INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

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INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

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Anacostia River Study
Phase 1

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I. INTRODUCTION

The Anacostia River Study is intended to identify water quality and physical habitat factors that limit the distribution of important fish species, and to create analytical tools that can be used to evaluate pollution abatement methods for their potential to improve fisheries habitat. This report describes the results of Phase I of the study, in which the effects of current water quality and physical conditions of the major tributaries of the Anacostia basin upon selected fish species are analyzed. Natural and anthropogenic limiting factors are evaluated in terms of the fish species ranges and abundances. Included in this report is a review of an instream flow methodology that could be used as an analytical tool in combination with appropriate water quality models for the assessment of present and potential fisheries distributions and habitat needs.

The Anacostia River Basin drains 169.9 square miles of land that is composed of two physiographic provinces, the Piedmont Plateau and the Coastal Plain. This creates diverse instream conditions that range from small turbulent gorges to slow moving tidal areas and includes stretches of pool and riffle areas. The geology, soils, hydrology/climate, and land use/cover have been detailed in various other reports (e.g. CH_2M Hill, 1982, COG, 1986, Century Engineering, 1985). The Maryland portion of the basin is dominated by urban land uses with agricultural and woodlands comprising the rest of the land. The only other significant land use in the basin is active and abandoned surface mining but this only accounts for a very small percent of the total drainage basin area. The major water quality problems that have previously been found in the basin are due to erosion and sedimentation and high levels of bacteria (e.g. Century Engineering, 1985, COG, 1986).

The first section of the report describes the current distribution of selected cool-water, warm-water and migratory fishes in the area. The cool-water fish analyzed are Brown Trout (Salmo trutta), and Rainbow Trout (Salmo gairdneri). The warm-water fish are Largemouth Bass (Micropterus salmoides), and Redbreast Sunfish (Lepomis auritus). Finally, the migratory fish are White Perch (Morone americanus), and River Herring (Alosa pseudoharengus & Alosa aestivalis). These fish were selected because they are currently found in the basin and they represent important fishes of the varying local environments in the area, both ecologically and because of their desirable recreational values. Information for this analysis was compiled using existing data bases and previous studies (Dietmann and Giraldi, 1973, Howden, 1948). Ongoing research databases were also used (ICPRB, 1989). Included in this section is a summary of habitat requirements for the selected species that was taken from the literature. These requirements are divided into two major components, water quality parameters and physical characteristics of streams.

Available water quality data from monitoring stations on the free flowing Anacostia and tributaries is summarized in the second section so that a detailed overview the current conditions is created. The locations of the monitoring stations used for this study are shown in Figure 1 (and this scheme is carried out for all subsequent figures). Each letter corresponds to a station whose data were extracted from the EPA STORET database. Letter 'G' actually represents the location of three monitoring stations that were found in the same general location. The scale of the map used for Figure 1 would not allow distinctions to be made for those three station locations (therefore the stations are referred to as 'G1', 'G2', 'G3', and 'G4'). This section updates the information provided in COG's (1986) 'Baseline Water Quality Assessment of the Anacostia Basin', and focuses on water quality parameters related to the fish species targeted for the present report. Conclusions are drawn about the relation of the fish distributions and water quality in the basin.

The second section also includes a summary of the National Pollution Discharge Elimination System facilities found in the basin. This summarizes the known sources of anthropogenic point source pollution to the receiving streams and is tied back to the fish distribution information where appropriate.

An overview of the physical habitat of the area is found in the third section. This section assesses the two main branches of the Anacostia (i.e. the Northwest and Northeast Branches) by application of an instream flow index. This is a simplistic model of the instream flow conditions at those places and is discussed in terms of the fish resources. The third section also reports the blockages to fish movement within the basin. Assessment of potential living resource enhancement by removal/modification of barriers is included and ranked in terms of potential benefit to migratory fishes. This identifies high priority blockages whose removal will have greatest benefit for migratory fish restoration and enhancement. Discussion of flood and erosion control structures follows and concludes with potentials for habitat enhancement by establishment of fringe marshes in some of these areas.

The fish distribution patterns that were detailed in the first section are analyzed in the fourth section with respect to the possible relationships of water quality and other habitat conditions found in this report. This summarizes the preceding sections results.

The potential benefits of modeling efforts are addressed in the last section as they relate to fishery resources and possible land use change. Models were analyzed for their ability to address the previously identified limiting water quality parameters, the pertinant land uses in the basin, as well as the geology, land cover, soils and physiography of the basin. The data needs for the recommended model development are discussed.

II. FISHERY RESOURCES

Fisheries populations in the Anacostia River Basin have been surveyed three times (Howden, 1948, Dietemann and Giraldi, 1973, and ICPRB, 1989). Results indicate that many areas of the Anacostia River are, and have been, in poor shape from a fisheries standpoint, however, there are some encouraging aspects. Thirty-one species were captured in 1948 and twenty-five were captured in 1972, using the shore haulseining technique. In 1987, forty-eight species were captured by the same technique. The apparent change in species composition is addressed in another report, but the increases in number of species captured and in ranges of some species suggest that modern pollution abatement programs may be showing signs of success (ICPRB, 1989).

In this report, we focus on several fish species that are widespread or desirable in the Anacostia River basin, and are representative of the different habitat types occurring in the basin. The fish selected for analysis include representative migratory anadromous, warmwater, and coolwater fishes. The anadromous fish selected are White Perch (Morone americanus), and River Herring (Alosa pseudoharengus and Alosa aestivalis). The warmwater fish include Largemouth Bass (Micropterus salmoides), Redbreast Sunfish (Lepomis auritus), and Bluegill (Lepomis macrochirus). The coolwater fish selected are Brown Trout (Salma trutta) and Rainbow Trout (Salmo gairdneri).

The current distribution of these species in the Anacostia River Basin, obtained from CH_2M Hill (1980) and ICPRB (1989), is presented in Figures 1 through 4. Among the most noteworthy points are the restrictions to spawning of anadromous fish by stream blockages to the tidal Anacostia, the restriction of reproducing populations of Brown Trout to upper Paint Branch, and the absence of all the selected species from Sligo Creek. The fish fauna of Sligo Creek was found to be very depauperate, with low densities and few species of fish present (ICPRB, 1989).

The habitat requirements, including both water quality and physical parameters, of the selected fish species were determined from the literature. These requirements are summarized in Tables 1 through 3. In subsequent sections of this report these habitat requirements will be interfaced with information on existing environmental conditions in the Anacostia River Basin.

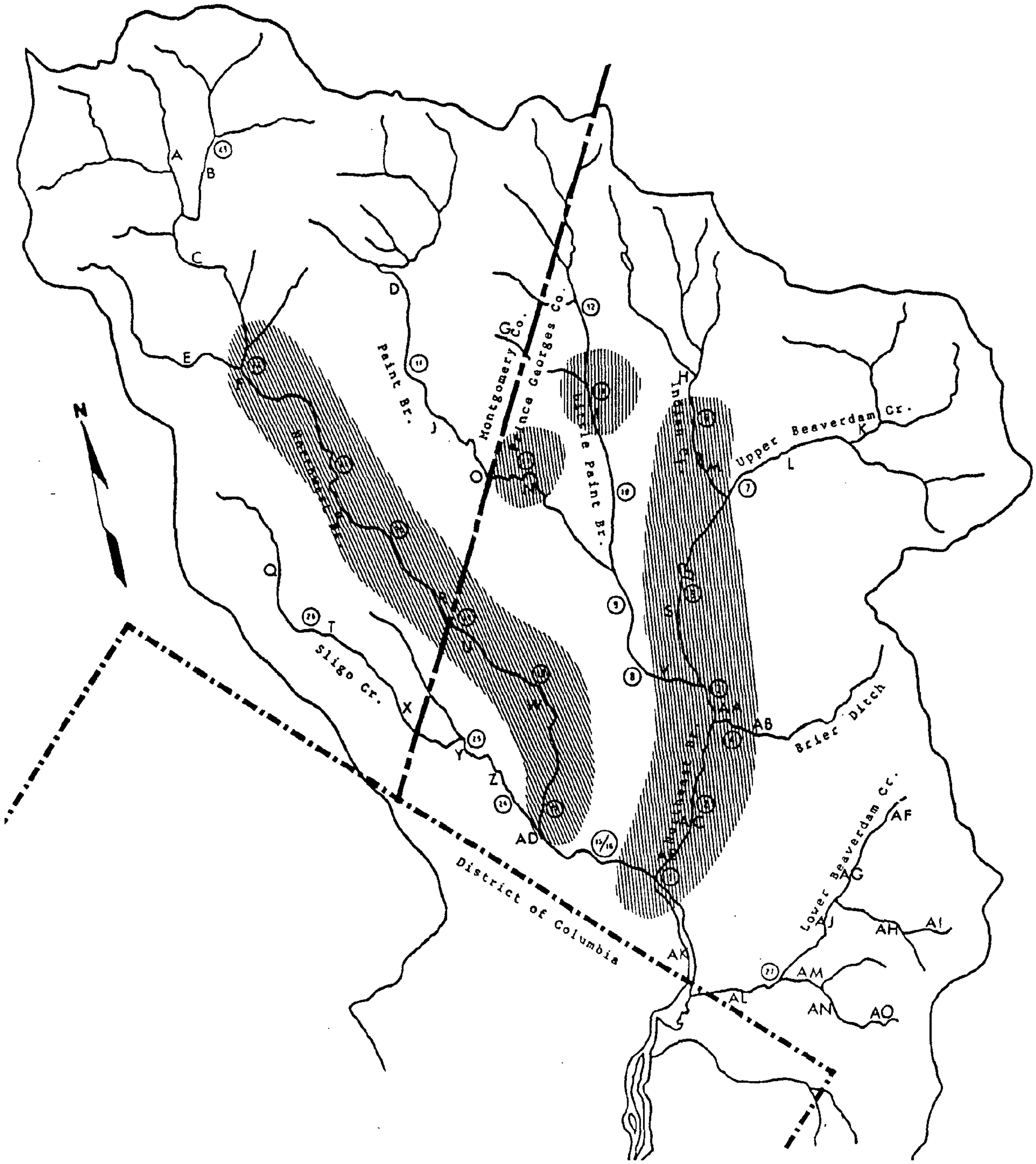

Figure 1. Distribution of Largemouth Bass in the Anacostia River Basin (source: ICPRB, 1989). Letters show location of water quality monitoring stations. Circled numbers show location of fish survey stations (ICPRB, 1989).

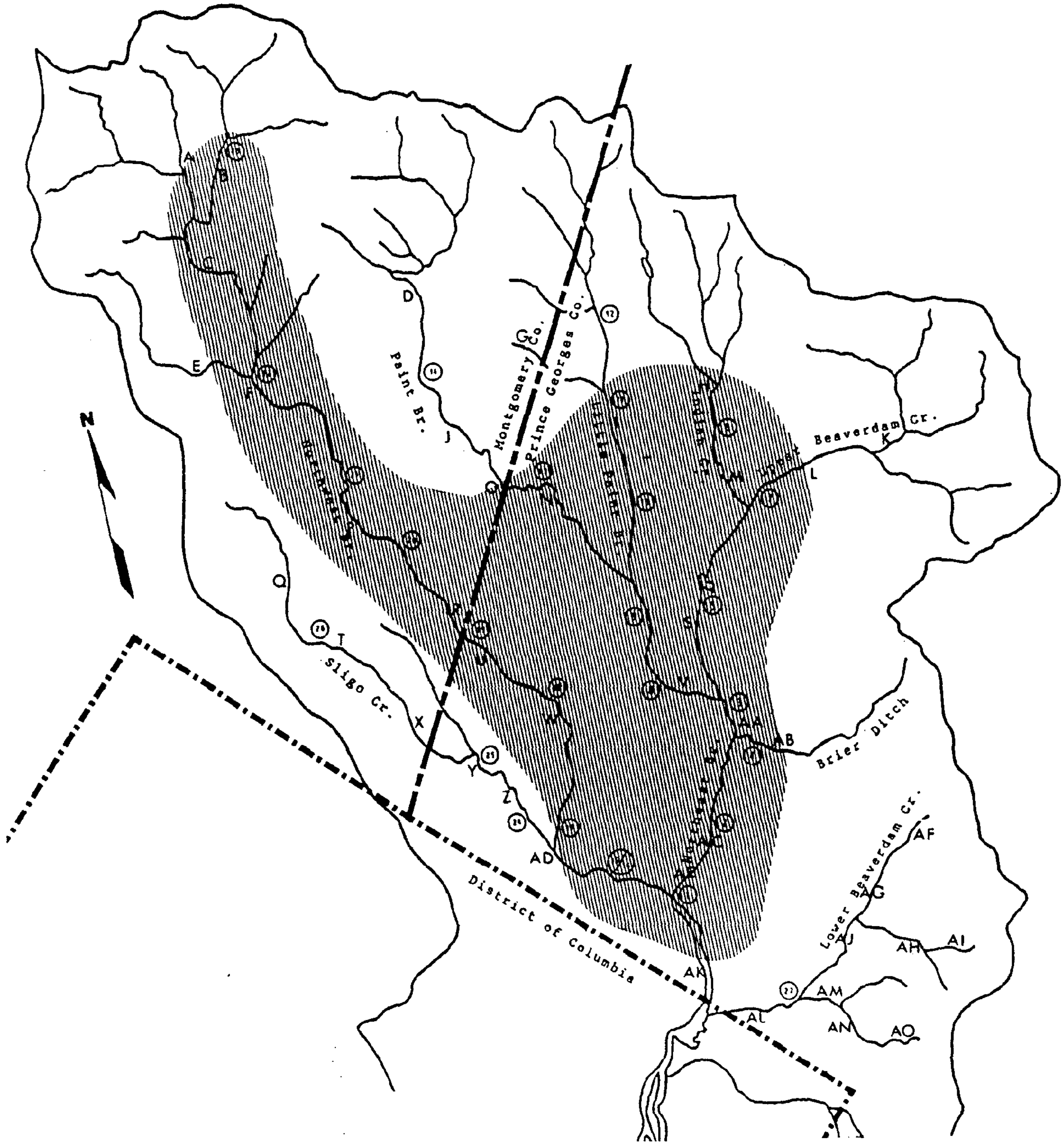

Figure 2. Distribution of Redbreast Sunfish in the Anacostia River Basin (source: ICPRB, 1989).

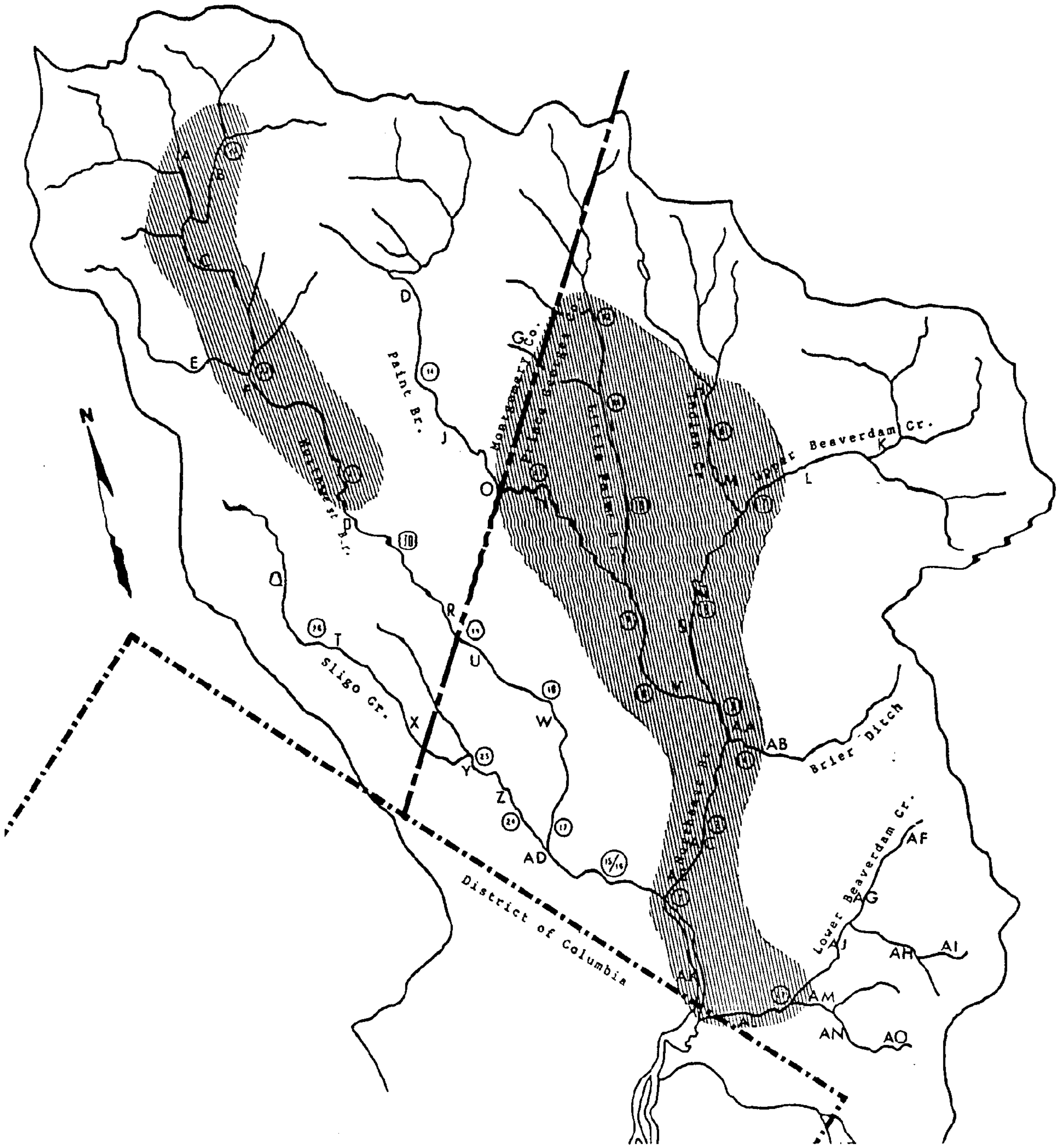

Figure 3. Distribution of Bluegill Sunfish in the Anacostia River Basin (source: ICPRB, 1989).

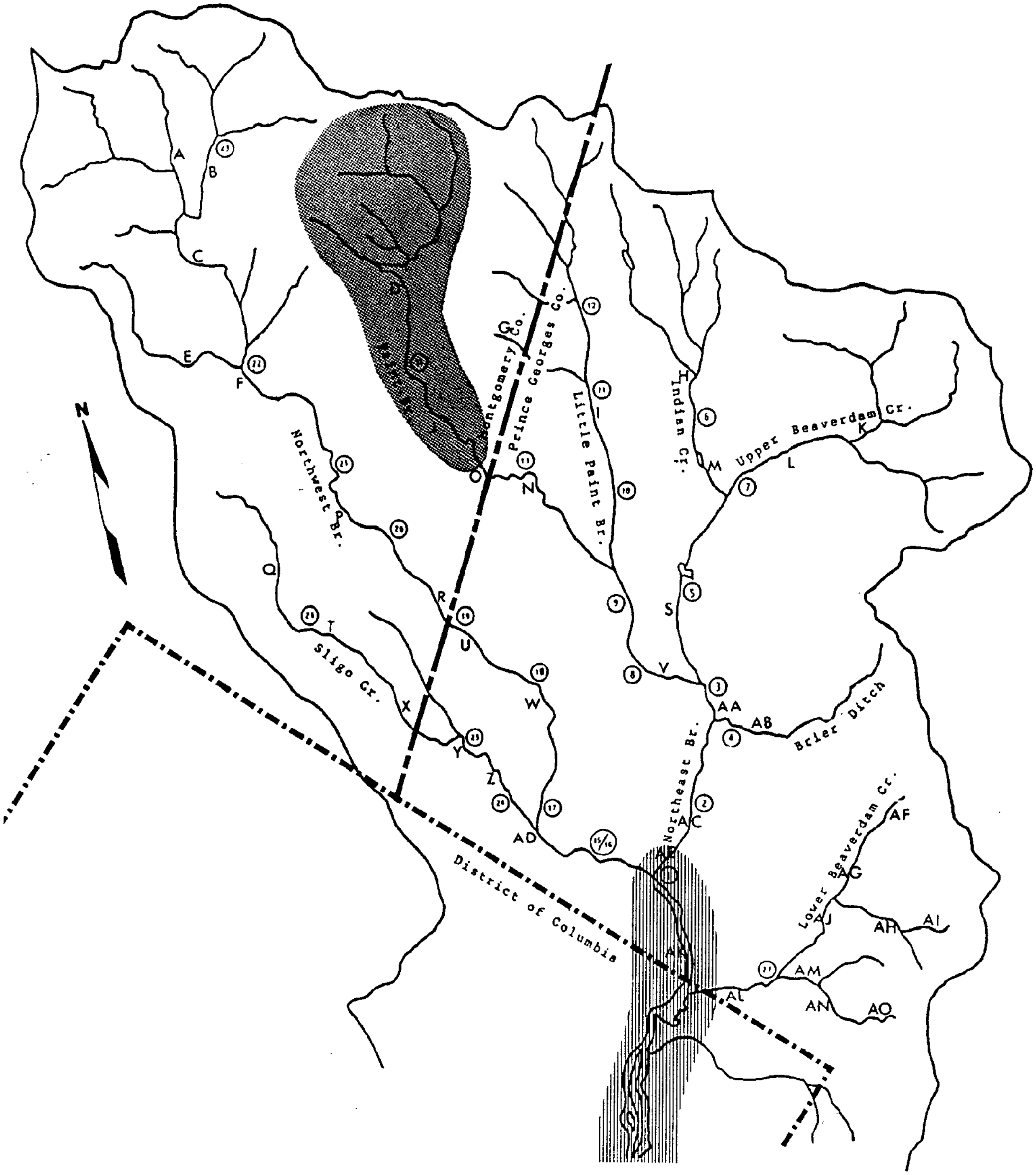

Figure 4. Distribution of Brown Trout (▒), and White Perch (|||||||), in the Anacostia River Basin (source: ICPRB, 1989).

Table 1. Habitat requirements for selected warm-water fishes.

	Largemouth Bass (*Micropterus salmoides*)	Redbreast sunfish (*Lepomis auritus*)	Bluegill (*Lepomis macrochirus*)
Water Quality Parameters:			
Water temperature	Spawning: 16-18°C optimum[1], tolerate 15.5-26°C[2] Subadults-adults: optimum 25-28°C[1] tolerate 10-30°C[2]	Acute LD_{50} >37°C[3]	Prefer 28-33°C[3]
Dissolved oxygen	Spawning and larvae: >4.5 mg/l[1] Adults: >2.85 mg/l[4]		Acute exposure to <3.6 mg/l reduces survival [3]
pH	Spawning and larvae: 6.5-10[1]	Occur in waters ranging 4.8-8.4[3]	
Physical Parameters:			
Substrate	Spawning: Gravelly substrate to marl and soft mud in reeds, bullrushes, or water lilies[1]		Spawning: Variety of substrates, but fine gravel-sand preferred[3]
Flow		Pool inhabitant, in Maryland streams occurred at volume flows 1.6-59.7 cfs[5]	Pool inhabitant, in Maryland streams occurred at volume flows 0.1-59.7 cfs[5]

1 Jones, et al. (1988)
2 Coutant (1975)
3 Carlander (1977)
4 Cech, et al. (1979)
5 Tsai and Wiley (1983)

Table 2. Habitat requirements for selected cool-water fishes.

	Brown Trout (*Salmo trutta*)	Rainbow Trout (*Salmo gairdneri*)
Water Quality Parameters:		
Water temperature	Spawning: 6.7-9°C[1] Subadults & adults: <24°C[1,2]	Spawning: 10-16°C[1] Subadults & adults: <28°C, optimum <21°C[1,2]
Dissolved oxygen	>5 mg/l[3]	>5 mg/l[3]
pH	Spawning: prefer 7-8.2[4]	Short term exposure to <5.5 inhibits reproduction and larval survival.[5,6] Higher levels likely required for long term development.
Suspended Solids		Sublethal stress at chronic exposure to 2-4 g/l (steelhead trout)[7]
Physical Parameters:		
Substrate	Spawning: Gravel areas of streams,[1] prefer mean sediment size 7-15 mm[4,8]	Spawning: Gravel areas of streams[1]
Flow	Volume flow for spawning: 0.7-21.2 cfs[4] Preferred flow velocities: Feeding 18-27 cm/s Spawning 31-47 cm/s[4,8]	
Depth	Preferred for feeding: 20-65 cm Preferred for spawning: 14-43 cm[8]	
Gradient	Preferred 0.2-2.3%[4]	

[1] Jones, et al. (1988)
[2] Carlander (1969)
[3] Mills (1971)
[4] Witzel & MacCrimmon (1983)
[5] Hulsman, et al. (1983)
[6] Weiner, et al. (1986)
[7] Redding, et al. (1987)
[8] Shirvell & Dungey (1983)

Table 3. Habitat requirements for selected migratory fishes.

	White Perch (*Morone americanus*)	River Herring (*Alosa pseudoharengus* & *A. aestivalis*)
Water Quality Parameters:		
Water temperature	Egg, larval stages: optimum 12-20°C[1] tolerate 11-30°C[1]	Spawning: Alewife 10-21°C[2] Blueback Herring 14-27°C[2] Larvae: 16-24°C[1] Young-of-the-year: >15.5°C[2]
Dissolved oxygen	All stages: >5 mg/l[1,2]	Young-of-the-year: >3.6 mg/l[2] Other life stages: >5 mg/l[1,2]
pH	Egg, larval stages: 6.5-8.5[1,2] Young-of-the-year: 7-9[2]	Egg larval stages: 6.5-8.5[1]
Suspended Solids	Egg, larval stages: <70 mg/l[1]	Egg, larval stages: <50 mg/l[1]
Turbidity	Egg, larval stages: <50 NTU[1]	Egg, larval stages: <50 NTU
Physical Parameters:		
Substrate	Egg, larval stages: compact silt, sand, mud, clay[1]	Egg, larval stages: Sand, gravel with 75% silt[1]

1 Chesapeake Bay Living Resources Task Force (1987)
2 Jones, et al. (1988)

III. WATER QUALITY SUMMARY

Water quality data were obtained from a variety of sources including the EPA's STORET and Permit Compliance System (PCS), the State of Maryland (Maryland Department of the Environment, 1986,1988), the Interstate Commission on the Potomac River Basin (ICPRB, 1989), and the Washington Metropolitan Council of Governments (1986). COG reported a 'baseline' water quality assessment of the Anacostia River Basin in 1986 and the information that follows updates much of that original work.

III.1. SEDIMENTATION

Century Engineering (1981) identified all sources (to 1981) of sediment in the Anacostia basin and rated them according to total contribution of sediment to the Anacostia River. By application of the Universal Soil Loss Equation (i.e. Computer Program for Gross Erosion, Sediment Yield, and Sediment Storage (SEDEL), USDA), abandoned and operating surface mines produced 48% of the sediment (i.e. 22,852 tons/mi^2/yr) and construction sites produced 13% (i.e. 10,675 tons/mi^2/yr). This is interesting because these forms of land use accounted for only 2% and 1% respectively, of the drainage basin area. Most surface mines were found in the areas of Little Paint Branch and Indian Creek. Another interesting point of this study was that sediment yield from the more urban areas was somewhat low (i.e. urban lands accounted for 12%, or 276 tons/mi^2/yr, of the sediment yield while occupying 44% of the land area). However the increases in runoff rates associated with these areas can cause accelerated streambank erosion and contribute sediment by this process to downstream areas. That report concluded that sediment yields will change under projected future land uses with general reductions in the highest yields, and some increases where urban/suburban construction projects increase. In particular, the large proportion of sediment that is attributed to mining are priority areas for management practices.

CH2MHill (1982) estimated the average annual sediment yields for existing and "ultimate" land use conditions for the Anacostia basin. Results of this study, like the Century Engineering (1981) report, show that future land use changes could accelerate sediment yield in sensitive areas if sound management practices are not applied.

Sediment problems in the Anacostia basin have been shown to be a major water quality problem by several other reports (e.g. MD DNR, 1984, MDEP, 1984, Century Engineering, 1985). Ragan and Rebuck (1973) state that the reduction in the observed number of fish species in the Anacostia basin could probably be attributed to erosion and sediment problems because the chemical characteristics of the water were good. However COG (1986) reported that erosion and sediment yield have decreased in recent decades as a result of land use changes and implementation of soil conservation and erosion practices.

Thus it is difficult to link sediment and erosion problems with fish distributions in the basin in any quantitative way at this time. However, there is evidence that poorly managed areas degrade habitat but could possibly be avoided in the future. It is important to note that certain streambed erosion control practices have actually been implicated as being detrimental to habitat quality in certain cases. This is discussed further in a later section.

TEMPERATURE

There is a temperature water quality standard of less than or equal to 32° degrees anywhere, anytime in all Maryland streams. Paint Branch is one of the exceptions and has a standard of less than 20 degrees. The 32 degree standard was very rarely exceeded, however the 20 degree standard for Paint Branch was exceeded in a Montgomery County station (i.e. station 50120 or "D" on Figure 5) on different occasions (the maximum was recorded as 22 degrees centigrade). Figure 5 also shows that the standard has been exceeded in stations "O" (i.e. 23 degrees) and "N" (i.e. 26 degrees). Unfortunately, data records on STORET for stations "O" and "N" end in 1982 and 1980 respectively, and station "D" has only one additional observation since 1986.

There is a spatial pattern of maximum temperature distributions in the basin as shown in Figure 5. Though it is difficult to make comparisons between stations with different recording histories, this map does have the virtue of providing a "quick and dirty" overview. It is clear that stations in the lower portion of the basin (Lower Beaverdam Creek, Lower Northwest and Northeast Branches) have higher maximum temperatures than other portions of the basin (i.e. temperatures there range from 26 to 32 degrees centigrade and from 22 to 26 elsewhere). The spatial pattern of median temperatures is less clear, but Lower Beaverdam Creek appears to be the warmest tributary (i.e. a range of 14 to 16 degrees centigrade, Figure 6).

Maximum temperatures do not clearly differentiate the upper Paint Branch, where reproducing brown trout populations occur, from other tributaries in the upper basin. Temperatures in upper Paint Branch are similar to those in upper Northwest Branch, upper Beaverdam, and Indian Creeks. However, it should be noted that the water quality monitoring stations on Paint Branch are downstream of the highest quality trout habitat (CH2M Hill, 1980). Water temperatures may be somewhat cooler closer to thesources of upstream springs. The high water temperatures in the lower portion of the Anacostia basin noted above do make these areas unsuitable for trout populations (Table 2). Otherwise, fish distributions would not seem to be restricted by water temperature. In particular, the depauperate fish fauna in Sligo Creek cannot be attributed to extreme temperatures by the available data from this tributary.

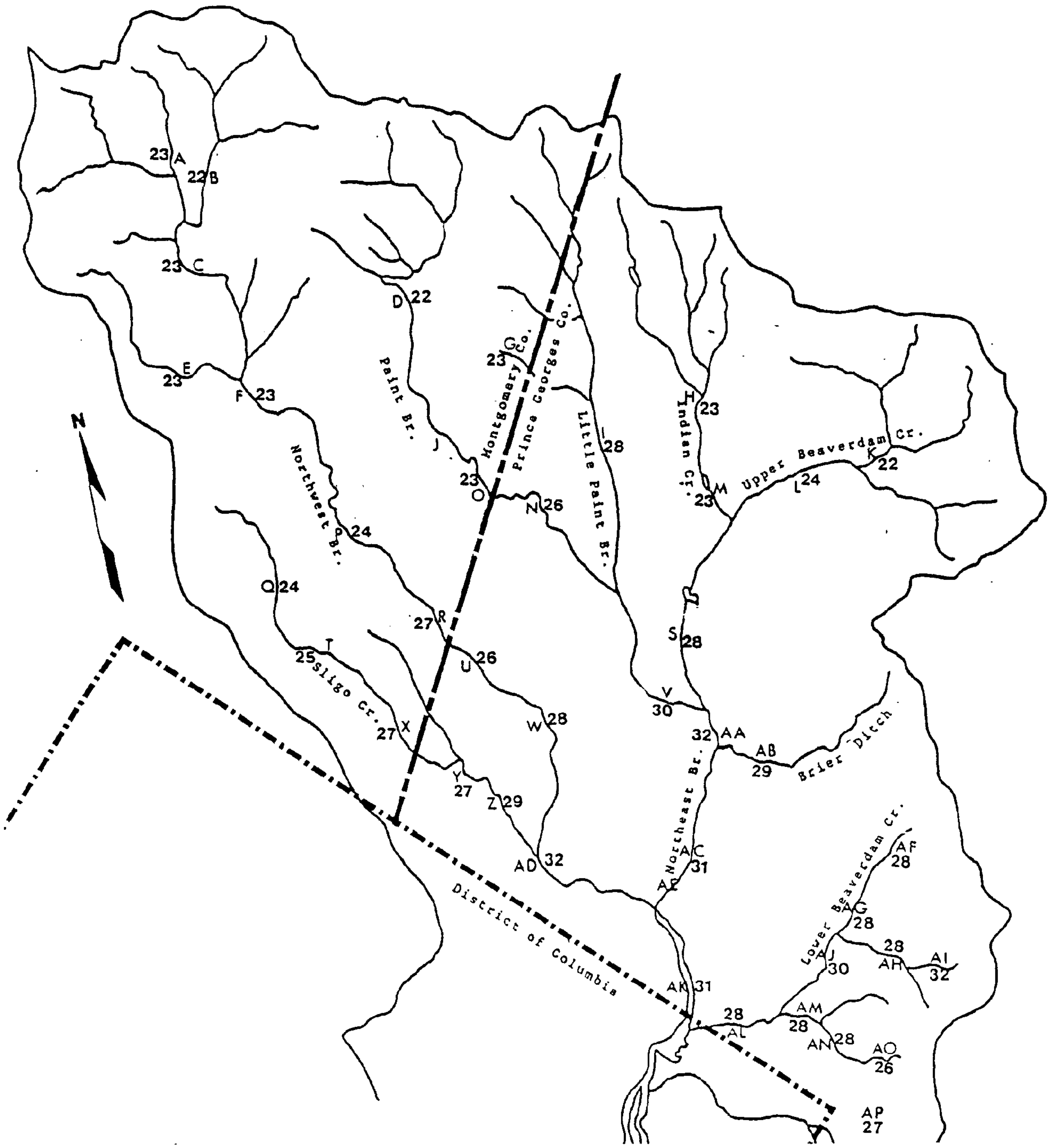

Figure 5. Maximum water temperatures (Centigrade) from the water quality monitoring stations in the Anacostia River Basin.

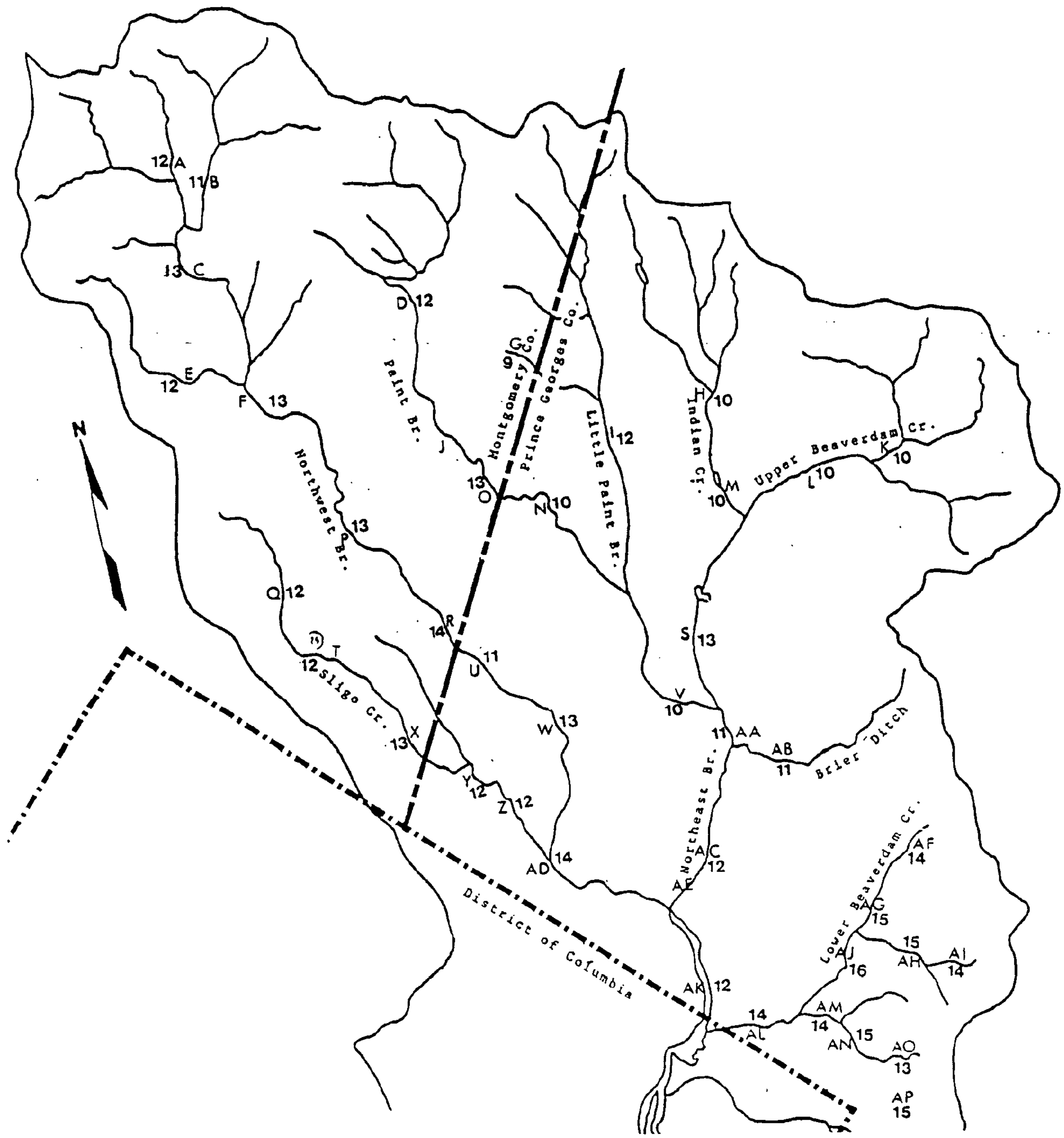

Figure 6. Median water temperatures (Centigrade) from the water quality monitoring stations in the Anacostia River Basin.

pH

The Maryland standard for pH is between 6.5 and 8.5. A map was made of the median pH values for each station for the present study. The pH values were near neutral in all stations with no obvious spatial pattern.

TURBIDITY and TSS

Maryland standard for turbidity is 50 JTU (monthly average) and less than 150 JTU anytime, anywhere. COG (1986) reports that there were several occasions of non-compliance and points out that violations may be frequently unobserved because measurements are typically made between storm events.

CH2MHill (1984) showed that TSS was highly correlated with storm flows in the Anacostia. After comparing several studies of TSS during storm flows in the Anacostia and Potomac river systems, COG (1986) reported that the Anacostia carries sediment concentrations that are roughly equivalent to the nearby Potomac tributaries but the TSS concentrations are much higher than in the Potomac itself. Both turbidity and TSS data were not as abundant as the other water quality data for the basin, however analyses of the available data showed no obvious spatial pattern within the basin.

BACTERIA

Maryland's Fecal Coliform standard is 200 MPN. In the present study both fecal and total coliform were analyzed and the results show that the standard is exceeded in most stations. Figure 7 shows the median values of total coliform for each station analyzed in the basin. Several observations can be made. Much lower coliform counts are found in the stations above (i.e. northwest) of the fall line (this roughly corresponds to those stations in Montgomery County). In that area, coliform counts range from 1000 to 8000 MPN/100ml. Below the fall line, the values are in general, an order of magnitude higher than other stations. Again, this type of comparison must be done with caution due to the inconsistent period of record between stations (period of record can be found for each station from Appendix I). Fecal coliform data (not shown) exhibit patterns similar to total coliform. Median values exceed Maryland's fecal coliform standard at almost all stations. As with total coliform, fecal coliform levels tend to be substatially lower in stations on Paint Branch and Northwest Branch than in other areas of the Anacostia River basin.

DISSOLVED OXYGEN

The Maryland standard for dissolved oxygen is a daily average of greater than or equal to 5 mg/l and a daily minimum concentration of greater than 4 mg/l. This study could not conclude that there are any dissolved oxygen problems despite the fact that high temperatures are of some concern in certain locations.

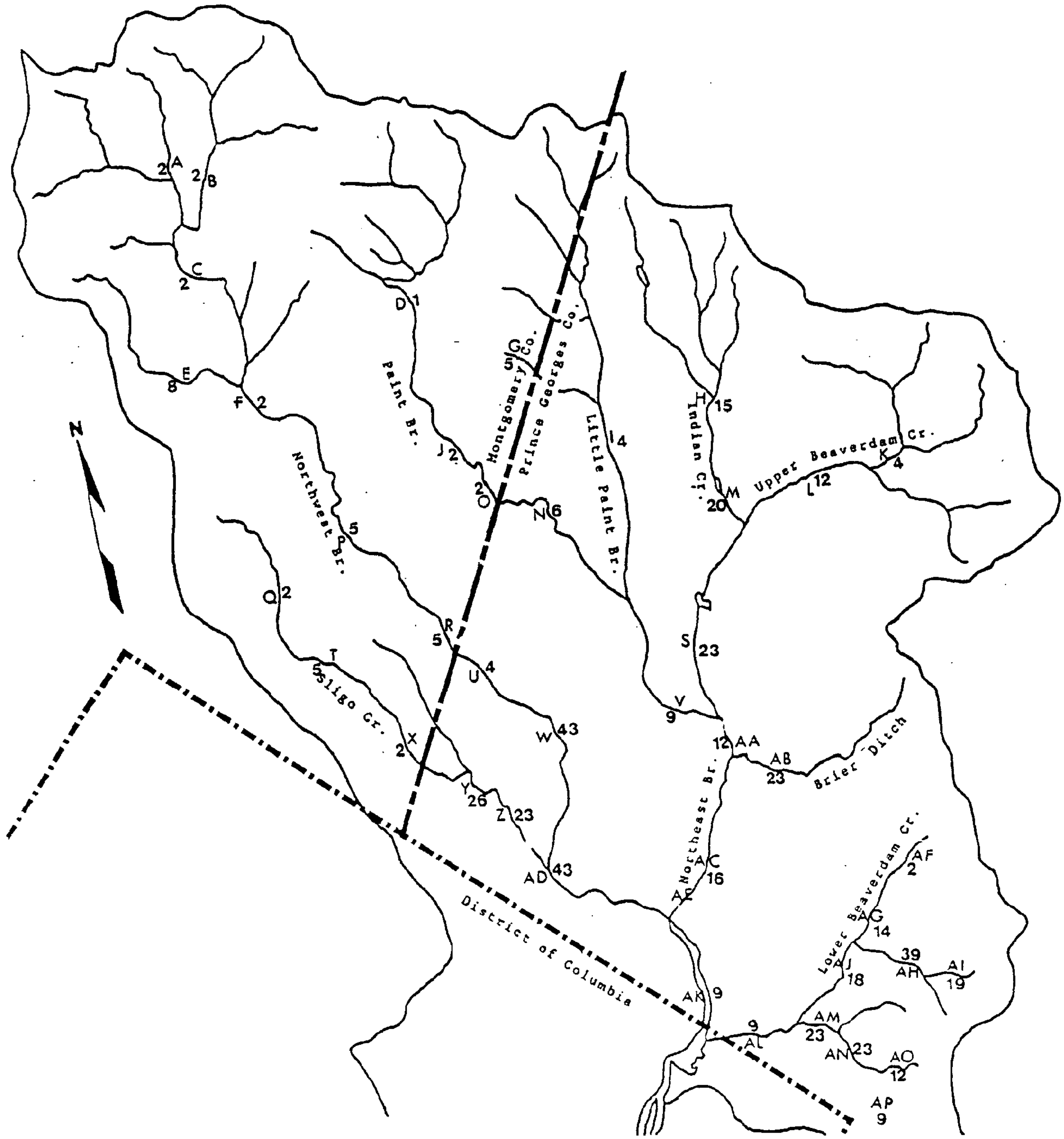

Figure 7. Median total Coliform (X 10^3MPN/100ml) from the water quality monitoring stations in the Anacostia River Basin.

III.2. TOXIC SUBSTANCES

Data were analyzed from two monitoring stations for several trace elements. These stations were upstream (i.e station #50113 or 'J' on our maps) and downstream (i.e. station #50110 or 'N' on our maps) of the U.S. Naval Surface Weapons Center which is one of the largest NPDES permitted facilities in the basin. Mean and maximum values of Copper, Lead and Nickel were much greater downstream from the facility than upstream. COG (1986) suggested that this facility may be a source of these elements. Data analyzed since 1986 (see Table 4) show that the downstream station continues to have higher levels these elements. For example, median Copper concentrations were 4.2 ppm upstream and 21.3 ppm downstream, median Lead concentrations were 3.6 ppm upstream and 6.3 ppm downstream, and median Nickel concentrations were 8.7 ppm upstream and 29.9 ppm downstream. Since the 1986 report Copper was monitored 20 more times at the upstream station and 19 times at the downstream station (according to STORET), Lead was monitored 41 more times at the upstream location and 40 more times at the downstream location, but Nickel was only monitored one more time at the upstream location and no more times at the downstream location. A comparison with federal water quality criteria for aquatic life shows that trace element concentrations at both of the monitoring stations are disturbingly high (Table 4). Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Silver and Zinc have at some time exceeded these criteria, and in fact the MEAN values of most of them are higher than the 24 hour and/or maximum exposure concentrations. This suggests that there may be other sources of these elements (e.g. natural sources) in the area of the U.S. Naval Surface Weapons Lab other than the lab itself. Therefore, conclusions cannot be drawn at this time about the source of the high concentrations of these elements in this area.

A comparison of data values of elements since 1986 shows that all elements have lower mean concentration values in 1988. However, the maximum values of Arsenic and Chromium have increased since the 1986 report in the downstream station (i.e. Arsenic maximum increased from 1.00 ppm to 1.40 ppm, and Chromium maximum increased from 46 ppm to 50 ppm). This is particularily alarming with respect to Arsenic because it has only 2 more observations since 1986.

Trace elements were analyzed in several other locations within the Anacostia River Basin in a report on the status and trends of toxic parameters in the Potomac River Basin (ICPRB, 1989). That study showed that increasing trends were detected in the Northwest Branch for Cadmium, Lead, Mercury, and Nickel. No other trends were detected within the basin (however, this may be due in part to limited available data). The high levels of these elements in the Northwest Branch further raises the question about the source of these naturally occurring substances.

The ICPRB toxics report (ICPRB, 1989) searched for many toxic substances other than the metals previously mentioned. However, the limited amount of data on other substances restricted that analysis in the Anacostia River Basin. Of the stations analyzed in that report, Cyanide and Phenols were detected at stations 'AC' and 'AD', on the Northwest and Northeast Branches respectively. Unfortunately, there wasn't enough available data at those stations to establish a trend analysis.

III.3. FISH TISSUE DATA

COG (1986) reported fish tissue data for White Suckers and Redbreast Sunfish from a station at Bladensburg Road. That information was given for 1980 and 1983 and has been supplemented in Table 5 with data for Redbreast Sunfish from 1984 and 1985 and includes data for Carp from 1985. The Food and Drug Administration defines action levels as limits at or above which the FDA will take legal action to remove adulterated products from the market (FDA, 1986). These levels were found for PCB, DDE, Chlordane, Dieldrin, and Mercury and are given in Table 5. It is important to note that the data in Table 5 are samples taken from whole fish, whereas the action levels are for edible portions of the fish. Furthermore, the action levels are composite samples and thus represent 'average' values, while the data in Table 5 are taken from a few individuals of specific species. The Carp data from 1985 were taken from only one observation, the White Sucker data for 1983 were from two observations, and the Redbreast Sunfish data from 1983, 1984, and 1985 were from three, four, and five observations respectively. Therefore, direct comparisons of the measured tissue data and the action levels cannot be made, the action levels can only be used as a relative guide to the data of Table 5.

Table 4. Trace elements from two monitoring stations in Paint Branch

	UPSTREAM Station 50113 (J)						DOWNSTREAM Station 50110 (N)					
	--to 1986--			--to 1988--			--to 1986--			--to 1988--		
ELEMENT	MAX	MEAN	#	MAX	MEAN	#	MAX	MEAN	#	MAX	MEAN	#
Arsenic	0.90	0.33	7	0.90	0.26	9	1.00	0.41	7	1.40	0.32	9
Barium	140	52.7	11	140	48.3	12	160	57.5	12	160	57.5	12
Cadmium	40	3.2	34	40	2.0	77	20	2.8	39	20	1.9	80
Chromium	50	4.7	28	50	4.8	43	46	5.9	31	50	5.6	46
Copper	34	4.8	27	34	4.2	47	752	32.9	28	752	21.3	47
Flouride	0.18	0.10	9	0.18	0.08	11	0.26	0.11	12	0.26	0.11	12
Iron	1150	182	29				1000	177	32			
Lead	28	5.5	36	28	3.6	77	141	10.7	40	141	6.3	80
Mercury	0.10	0.05	3				0.10	0.04	4			
Nickel	19	9.4	12	19	8.7	13	284	29.9	13	284	29.9	13
Selenium	0.50	0.21	11	0.50	0.19	12	0.60	0.26	11	0.60	0.24	12
Silver	2	0.45	11	2	0.42	12	5	1.0	12	5	1.0	12
Zinc	107	15.0	37	107	9.9	77	111	16.6	41	111	11.5	79

WATER QUALITY CRITERIA FROM FEDERAL REGISTER
Vol. 45, No. 231

ELEMENT	AQUATIC LIFE		HUMAN HEALTH	WELFARE
	Max	24Hr	Max	Max
Arsenic	440			
Barium			1000	
Cadmium	.025		10	
Chromium	21	.029	170	
Copper	7.1	5.6	1000	
Flouride				
Iron	1000			300
Lead	170	3.8	50	
Mercury	.0017	.0006	.145	
Nickel	1800	96	100	
Selenium	260	35	10	
Silver	4.1	.12	50	
Zinc	47			5000

Note: All units are in ug/l except Flouride (mg/l).

Table 5. Summary of Fish Tissue Analysis at Bladensburg Road for White Suckers, Redbreast Sunfish, and Carp (ppm).

	1980 Suckers	1983 Suckers	1983 Redbrst	1984 Redbrst	1985 Redbrst	1985 Carp
ORGANIC COMPOUNDS						
PCB (1260)	.45	.245	.208			
DDE	.03	.026	.012	<.07	<.07	<.07
DDD	.02	.117	.08	<.04	<.04	<.04
Chlordane	.15	.176	.934	.08	.06	.39
Dieldrin	.007	.017	.017	.042	<.007	<.007
Decthal	trace					
HCB	.002				<.002	<.002
BHC (Alpha)		<.002	<.002	.006	<.002	<.002
METALS						
Arsenic	<.05	.12	.13	.11	.31	.35
Cadmium	.20	.30	.60	.09	.36	.37
Chromium	.13	1.70	<.50	<.50	.50	<.50
Copper	.75	1.04	1.24	6.81	1.09	1.67
Lead	1.00	2.90	4.20	1.40	.90	1.90
Mercury	.159	.027	.041	.054	.046	.025
Zinc	13.8	18.3	30.0	7.35	6.99	71.0

FDA Action Levels

PCB	2.0
DDE	5.0
Chlordane	0.3
Dieldrin	0.3
Mercury	1.0

III.4. NPDES FACILITY SUMMARY

There are several 'minor' (i.e. < 1 MGD) facilities in the basin. In order to obtain information on these sites three sources were used; EPA STORET (i.e. WQAB), EPA PCS, and the State of Maryland Department of the Environment. A comparison of these sources showed that the information was not consistent in certain respects (e.g. there were facilities listed in one data base that were not in the others). Also, the EPA data bases provided limits information on only a select few locations and, information on any minor discharger is scarce. Therefore a summary of the permitted facilities in the basin was compiled from the files at the MDOE (see Table 7). Note that this Table may not contain every permitted facility in the basin but does provide a good picture of the types of discharges in the area. Also, some of the permits have expired and therefore some of the facilities may not be discharging to surface waters anymore. Therefore the compilation is an historical overview. Figure 8 shows the approximate locations of these facilities.

Two major (i.e. discharge of > 1 MGD) facilities that were permitted under NPDES are the Mineral Pigments Corporation (Figure 8, Facility #21) and the U.S. Naval Surface Weapons Lab (Figure 8, Facility #22). The Mineral Pigment Corporation is given a SIC code of 'Inorganic Pigments' and discharges from outfalls into an Indian Creek tributary. The Navy Surface Weapons Lab has a SIC code of 'Ammunition, Exc. for Small Arm' and discharges from outfalls into Paint Branch.

An EPA Permit Compliance System retrieval was used to obtain permit limitation and violations summaries for these facilities. The Mineral Pigment Corporation had seven parameters listed for its outfall; pH, total suspended solids, Barium, Hexavalent Chromium, Total Chromium, Lead, and Zinc. The limitations for each parameter are summarized below for the outfall.

PARAMETER	LIMITATION (OUTFALL 001A)
pH	Minimum 6, Maximum 9
TSS	Average Quantity 16.7 lbs/day
	Maximum Quantity 33 lbs/day
Barium	Maximum Concentration 120 ug/l
Hexavalent Chromium	Average Concentration 0.15 ug/l
	Maximum Concentration 0.30 ug/l
Total Chromium	Average Quantity 2.39 lbs/day
	Maximum Quantity 5.7 lbs/day
Lead	Average Quantity 2.76 lbs/day
	Maximum Quantity 6.62 lbs/day
Zinc	Average Quantity 1.7 lbs/day
	Maximum Quantity 3.3 lbs/day

It is important to note that the permit limitations can also be a function of the process that is creating the discharge. For example at this facility the zinc effluent limit is increased to 1.78 lbs/day monthly average and 3.53 lbs/day daily maximum when the two outfalls are discharging simultaneously during zinc phosphate production. Unfortunately the PCS data base contained no information on violations at the Mineral Pigment Corporation. As of October 1988, all process wastes from this facility are discharged to a sanitary sewer controlled by WSSC and are therefore no longer discharged directly to the tributary.

The U.S. Naval Surface Weapons Lab has four different parameters listed in its permit: temperature, pH, total suspended solids, and oil and grease. An example of the limitations for a single outfall follow and is representative of the type of limitations for the other outfalls at the facility.

PARAMETER	**LIMITATION (OUTFALL 002A)**
Temperature	Maximum 22.2 degrees Celsius
pH	Minimum 6.0, Maximum 8.5
T.S.S.	Average Quantity 20 lbs/day, Maximum Quantity 40 lbs/day Average Concentration 28 mg/l Maximum Concentration 56 mg/l
Oil and Grease	Average Quantity 18 lbs/day, Maximum Quantity 38 lbs/day Average Concentration 25 mg/l Maximum Concentration 50 mg/l

Table 4 showed that the mean concentrations of Copper, Lead and Nickel were much greater at a monitoring station downstream of the U.S. Naval Surface Weapon Lab than they were just upstream of it, suggesting that the lab may be a source of these elements. Curiously, the effluent permit does not specifically include those elements.

A violations summary for the past four years was created for the U.S. Naval Surface Weapons Lab from the Permit Compliance System data base. This summary reports the number of violations for the given parameter for that year and the maximum violation (as a percentage deviation from the permitted value). The number of violations includes all violations from all outfalls (Table 6).

Table 6. Summary of NPDES permit violations for the U.S. Naval Surface Weapons Lab ('n' is the number of violations for all outfalls that year, 'Max.' is the maximum violation, in percent of permit limit).

PARAMETER	-1985-		-1986-		-1987-		-1988-	
	n	Max.	n	Max.	n	Max.	n	Max.
TSS								
Ave. Conc.	4	700	4	272	None		None	
Max. Conc.	4	521	15	3060	5	260	3	840
pH								
Minimum	None		2	13	2	10	1	10
Maximum	None		None		None		None	
Oil and Grease								
Ave. Conc.	None		6	660	3	147	1	50
Max. Conc.	None		7	1400	5	139	1	36
Temperature								
Maximum	None		11	13	1	1	None	

Table 7. List of past and present NPDES minor facilities.

MAP #	NAME	RECEIVING WATER	PARAMETERS
1	Amerada Hess Corp.	Beaver Dam Creek	Oil and Grease
2	AMOCO Service Station	Northwest Branch (storm sewer)	Benzene, Toluene, Xylene
3	Beltsville Agri. Res. Center	Groundwater	Heated water
4	Bonifant Rubble Fill	Groundwater	Landfill leachate
5	Capitol Wire and Fence Company, Inc.	Unnamed Tributary to Anacostia	Condensate water
6	Contee Sand and Gravel Company, Inc.	Paint Branch	Total Suspended Solids, Turbidity
7	D and D Service Station	Unnamed Tributary to Anacostia	Benzene, Toluene, Xylene
8	Harry Diamond Labs	Paint Branch	Oil and Grease, pH
9	Holy Cross Hospital	Sligo Creek	Total Suspended Solids, Turbidity, pH
10	Ilbau America Inc.	Unnamed Tributary to Sligo Creek	Total Suspended Solids, Oil and Grease, Turbidity
11	Laurel Sand and Gravel Inc.	Indian Creek	Total Suspended Solids, Turbidity, pH
12	Metro Subway Tunnels	Unnamed Tributary to Northwest Branch	Total Suspended Solids, Turbidity, Petroleum Hydrocarbons, pH

Table 7. List of past and present NPDES minor facilities (continued from previous page).

MAP #	NAME	RECEIVING WATER	PARAMETERS
13	Metro Subway Tunnels	Unnamed Tributary to Northwest Branch	Total Suspended Solids, Turbidity, Petroleum Hydrocarbons, pH
14	Nazario Construction Co. Inc.	Indian Creek	Total Suspended Solids, Oil and Grease pH
15	Pressure Science Inc.	Unnamed Tributary to Indian Creek	Oil and Grease
16	Seat Pleasant Amoco	Cabin Branch	Total Suspended Solids, BOD, Oil and Grease
17	Smith, A.H. Associated LTD.	Indian Creek	Total Suspended Solids, Turbidity
18	Univ. of MD Fire and Rescue	Paint Branch	Oil and Grease Benzene, Toluene, Xylene, pH
19	U.S. Metal Forms and Tubes Inc.	Indian Creek	Total Suspended Solids, Oil and Grease pH
20	Wheaton Tail Tunnels	Unnamed Tributary to Sligo Creek	Total Suspended Turbidity, pH

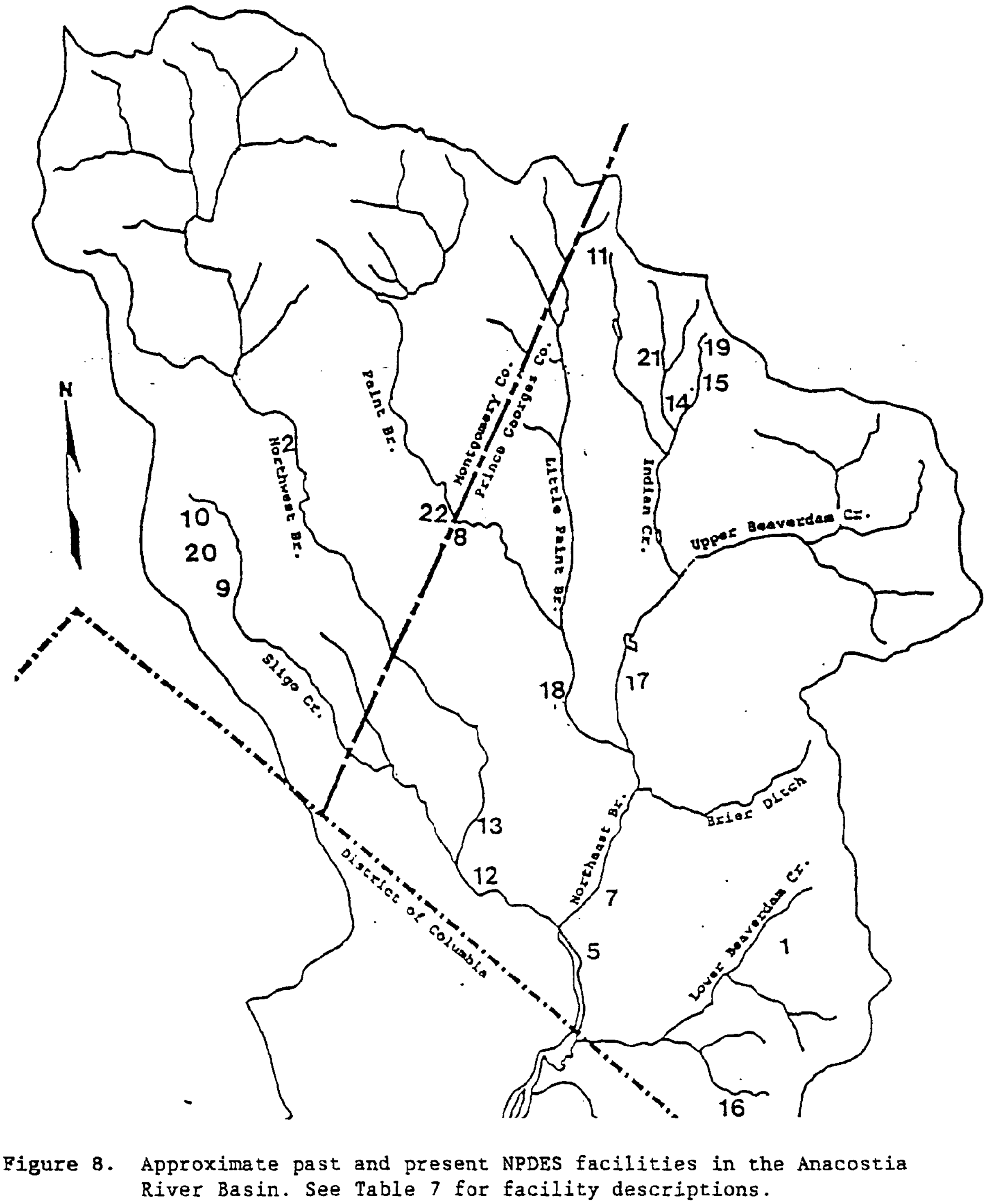

Figure 8. Approximate past and present NPDES facilities in the Anacostia River Basin. See Table 7 for facility descriptions.

IV. PHYSICAL HABITAT

Instream flow requirements refer to flow regimes in stream channels that are needed to sustain instream values at an acceptable level (Loar and Sale, 1981). Methods have been developed to assess the instream flow requirements for many stream uses, such as for recreation, aesthetics, aquatic biota, and maintenance of water quality. Of these uses, the instream flow needs of aquatic biota have been the most difficult requirements to develop.

Among the most commonly used approaches for assessing habitat quality for aquatic biota are those based on historical records for stream discharge. The best tested and most widely used of these is the Tennant or Montana method. In the Tennant method, the health of the aquatic habitat is related to percentages of the mean annual flow rate (MAF) occurring at the site of interest: 10% of MAF is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic biota; 30% of MAF is a base flow recommended to sustain good habitat; 60-100% of MAF is a base flow recommended to provide optimum habitat; and a flushing flow of 200% of MAF is recommended to maintain high quality habitat (Loar and Sale, 1981; Camp, Dresser, and McKee, 1986).

Long-term records of daily flows are available for two U.S. Geological Survey gages on the Northeast Branch Anacostia River at Riverdale (Station AC) and on the Northwest Branch Anacostia River at Hyattsville (Station AD). These records were used to calculate minimum and maximum daily flows as a percentage of MAF for the water years 1961 through 1987. Figures 9 and 10 show that minimum daily flows are usually near or below 10% of MAF, indicative of a severely degraded habitat by the Tennant method. Maximum daily discharges are roughly 1000% of MAF, well in excess of recommended levels.

Flow rates may be less variable in some of the smaller tributaries that drain the less urbanized areas.
For example, upper Paint Branch, which is fed by flowing springs and which is in a relatively undeveloped area, may have lower and more stable discharge rates that support more favorable habitat. This supposition is supported by limited measurements taken in November 1979 at several stations on Good Hope Tributary of Paint Branch. Flow rates ranged from 0.1 to 4.2 cfs (Galli, 1983), which is well within the preferred range for Brown Trout (Table 2).

Volume flows recorded at the USGS gauge stations would appear to be unfavorable for Brown Trout, and suboptimal for Bluegill and Redbreast Sunfish. Mean flow rates at both stations are above the range preferred by Brown Trout for spawning (Tables 1 and 2). Maximum discharge rates at both stations greatly exceed the range for which Bluegill and Redbreast Sunfish were found to occur in Maryland streams, but mean flow rates were often in their range of occurrence (Tables 1 and 2).

The Tennant method for stream habitat evaluation, like other discharge methods, has the advantages of being quick, inexpensive, and easy to use. It is the best tested of the discharge methods, and has been recommended as the best minimum instream flow estimation method for Virginia (Camp, Dresser, and McKee, 1986). However, it is a very oversimplified index, which omits consideration of many important aspects of stream habitat and water quality. More detailed methods for stream habitat evaluation, which may potentially be applied to the Anacostia River Basin, are discussed later in this report.

IV.1. FISH BLOCKAGES

Table 8 lists an inventory of potential migratory fish blockages in the Anacostia basin that was compiled during another ICPRB study (ICPRB, 1989). The approximate locations of these blockages are presented in Figure 11. The two 'Final Blockages' (i.e. Northwest Branch (f) and Northeast Branch (a)) are the first complete blockages encountered by migrating fish. These are labelled 'Final' because they do not allow passage beyond those points. The 'Partial Blockages' will restrict passage to certain fishes and at specific flow rates. Other blockages are termed 'Potential Future Blockage' to indicate that these structures will play an important role in fish migration if the 'Final Blockages' are removed.

An assessment of the priority for removal of blockages was made considering the potential benefit to increased access of upstream habitat and the amount of work required for the removals. The two 'Final Blockages' would at first seem to be of high priority (i.e. they are the farthest downstream of all blockages). However the benefits of removing the blockage on the Northwest Branch may not be as great as removing some blockages on the Northeast Branch. This is due to the fact that the Northwest Branch has many other 'Potential Future Blockages' (i.e. a, b, c, d, and e). These blockages would also require removal in order to open access to the upper Northwest Branch. In addition, Sligo Creek has many potential blockages.

Removal of the 'Final Blockage' on the Northeast Branch and the three other blockages on Paint Branch and Little Paint Branch (i.e. (a) and (b) on Paint Branch and (a) on Little Paint Branch) would provide the most access to the headwaters of important tributaries in the basin with the least amount of work required. This would open up larger amounts of area within the Coastal Plain regions of the basin. Therefore in terms of priorities, removal and or modifications of the blockages on the Northeast Branch should be first. It must be noted that providing access to upstream waters does not necessarily require total removal of some of these structures.

This could be supplemented by a careful plan of removal/modification of other blockages elsewhere in the basin. The plan must include considerations of the original intention of the targetted structure (i.e. some were intended for flood and/or erosion control such as velocity dissipators). It is our belief that a carefully considered plan could open up a great deal of upstream habitat while at the same time important structures could be modified so that their original purpose is maintained.

IV.2. WETLAND RESTORATION

Wetland vegetation can have a number of beneficial effects on stream water and habitat quality. Of particular importance to this study, it can be used to retard streambank erosion, cast shade that moderates water temperatures, and provide food and cover for fish and other aquatic organisms.

Though no extensive wetland mapping projects have been accomplished for non-tidal areas, field observations have shown that the heavy urbanization in the Anacostia River basin has resulted in large losses of riparian vegetation. Opportunities for wetland creation in the Anacostia River basin are limited because much of the watershed has already been allocated to other uses. Of these specific uses, flood control projects have most often conflicted with wildlife concerns. Flood control projects have channelized the streams, which removes vegetation and cover and creates thermal problems. Water temperatures as high as 35^{o}C have been measured in channelized areas (ICPRB, 1989), which would be deleterious to all fish (Tables 1, 2 and 3). Flood control projects have also armored the banks of streams, which can reduce availability of high quality habitat, although designs involving the use of large boulders with sufficient space between them do allow some refuges for fish and other aquatic organisms.

Some of the flood control projects have left large amounts of riparian areas covered with concrete. Obviously these areas would not be suitable for wetland restoration without major modifications of the existing structures. The areas with the highest potential benefits from wetlands restoration are in some of the flood and erosion control stretches. The primary areas of concern are the mainstem Anacostia River above the Bladensburg Marina, the Northwest Branch up to the East-West Highway, and the Northeast Branch downstream of Riverdale Road. Channelization in these places has required extensive areas of rip-rap to be installed to minimize streambank erosion. The amount of streambank vegetation is minimal or absent along these banks. These areas would benefit from the increased shading and habitat resulting from the establishment of fringe marshes. Species such as <u>Sagittaria latifolia</u> (Duck Potato or Big-leaved

Arrowhead), Scirpus validus (Softstem Bullrush), and Zizania aquatica (Wild Rice) are among those plants that could improve conditions in these areas. These are among the list of species recommended for planting on the tidal Potomac and Anacostia Rivers by the Baltimore District, Corps of Engineers. These species are common locally, are tolerant to regular or continued flooding, are easily established as pioneer plants, and are reasonably resistant to water movements likely to be encountered on the Anacostia River. Wild Rice was once widespread on the Anacostia River, and has been successfully established on the tidal Potomac and Anacostia Rivers in a joint ICPRB-National Park Service project.

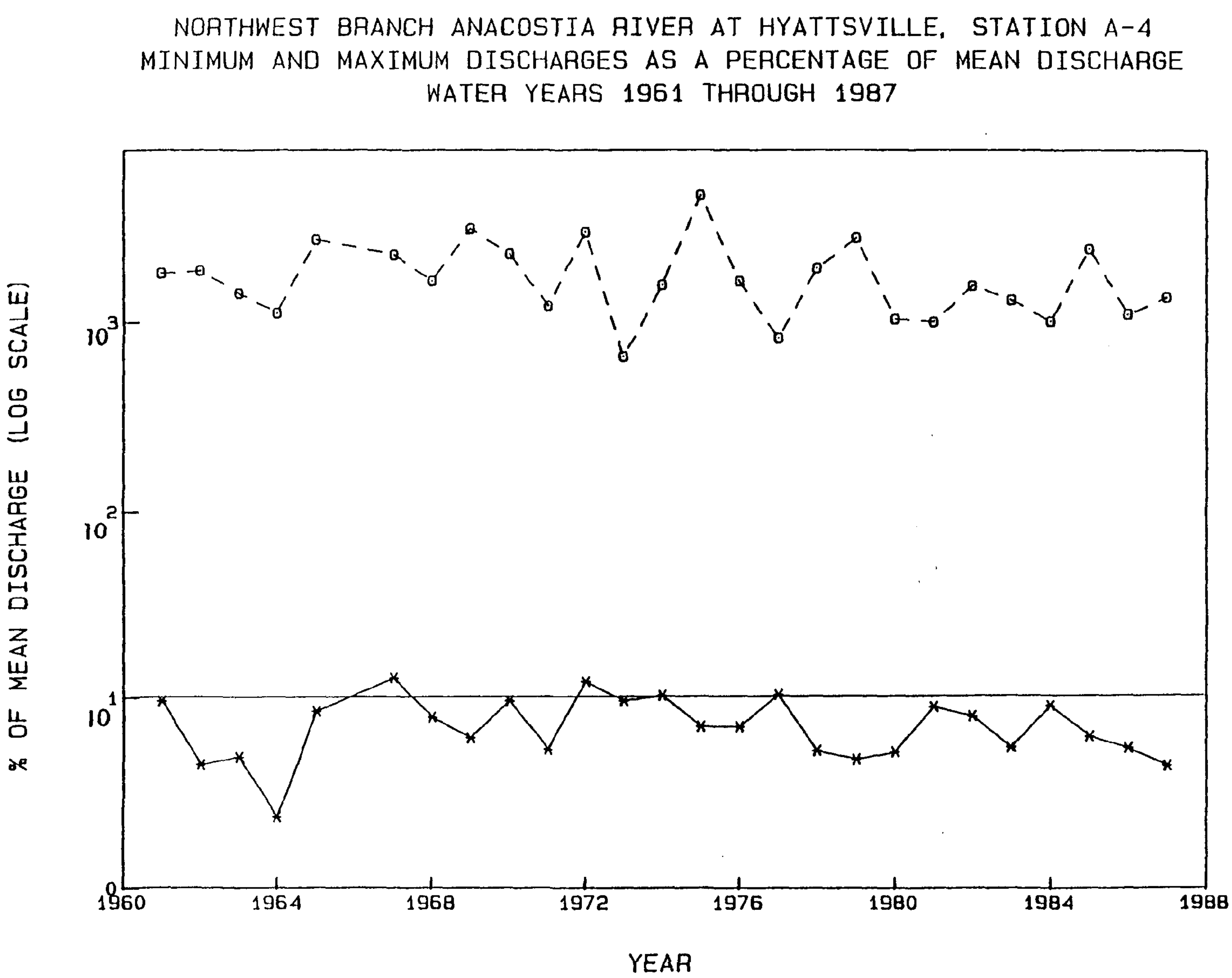

Figure 9. Tennant index for the Northwest Branch.

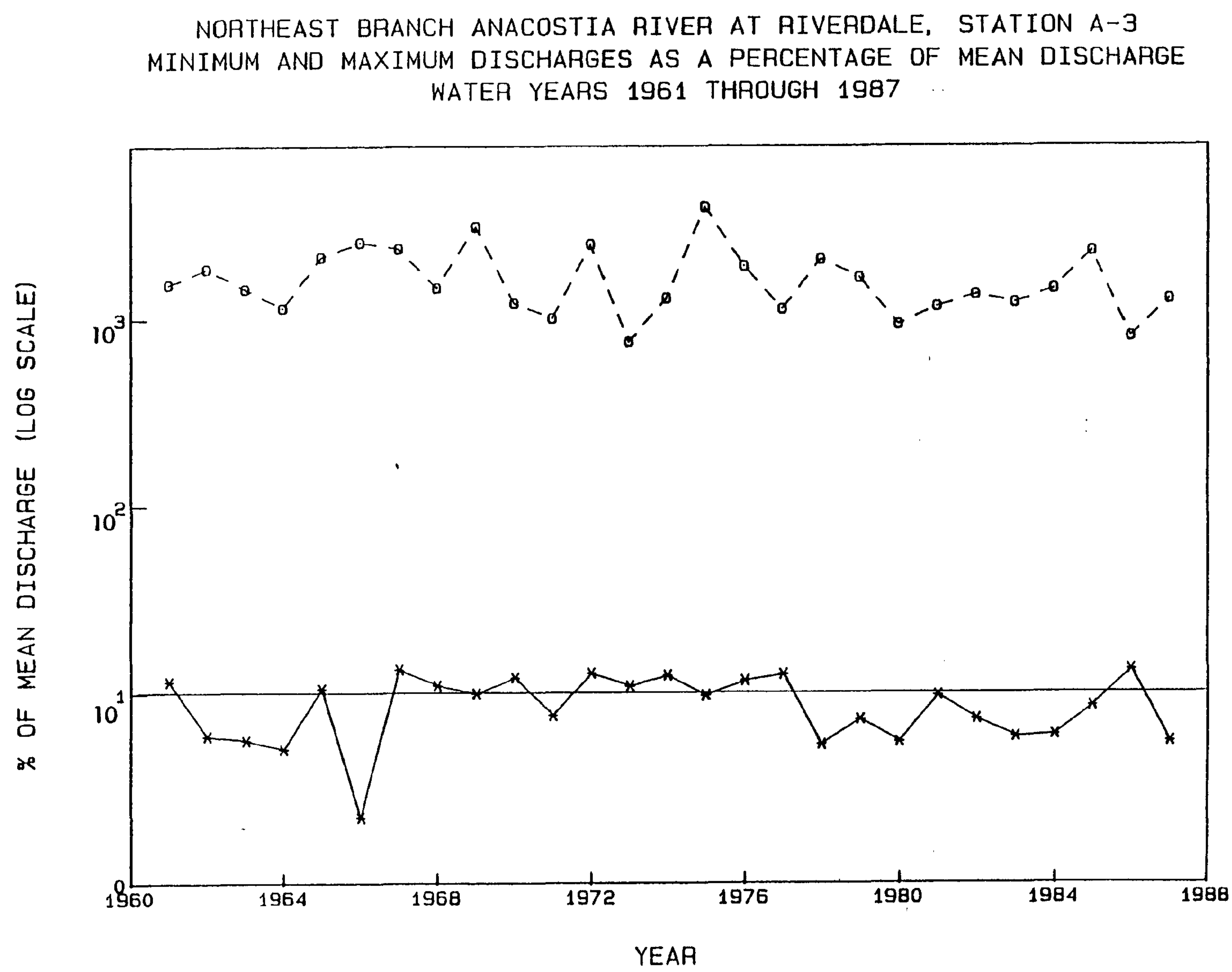

Figure 10. Tennant index for the Northeast Branch.

Table 8. Inventory of potential migratory fish blockages (source: ICPRB, 1989).

Tributary	Location	General Description	Estimated Height
Sligo Creek	A. 700' downstream from Piney Branch Road	Uncapped pipe	16"
	B. 1500' upstream from Carroll Avenue	Uncapped pipe	16"
	C. 250' upstream from Carroll Avenue	Uncapped pipe	12"
	D. 1000' upstream from Riggs Road	Concrete cap	24"
	E. At Riggs Road	Concrete channel with apron	FA*
	F. Four drop structures which step down to the confluence with the N.W. Branch.	Concrete steel, and rip-rap dams	To 24" each
N.W. Branch	A. 2000' upstream from 495	Concrete cap	12"
	B. 200' upstream from East-West Highway	Concrete cap	8"
	C. At the confluence with Sligo Creek	Gabion dam	12"
	D. 700' downstream from Queens Chapel Road	Gabion dam	18"
	E. 1000' upstream from 38th Street	Gabion dam	18"
	F. 100' upstream from 38th Street	Metal weir	8"
	G. At Route #1	Concrete apron	FA*
Paint Branch	A. Bridge at inner loop of I-495	Bridge culvert	4"
	B. 1000' upstream from the confluence with Indian Creek	Metal weir	12"
Lower Paint Branch	A. 3000' downstream from Sellman Road	Two concrete dams	12" each
Indian Creek	A. 1000' upstream from Branchville Road	Sand & gravel settling ponds	FA*
	B. 3000' upstream from the confluence with Paint Branch	Concrete cap	4"
Brier Ditch	A. At Kenilworth Avenue	Bridge culvert	6"
N.E. Branch	A. Behind MNCPPC building on Kenilworth Avenue	Metal weir	12"
	B. 3000' upstream from East-West Highway	Gabion dam	6"
	C. 500' downstream from Riverdale Road	Rip-rap chute	FA*
Lower Beaverdam Creek	A. 2000' upstream from Landover Road at the confluence of small concrete stream	Concrete splash	8"
	B. At Landover Road	Bridge culvert	16"
	C. At Kenilworth Avenue	Concrete spillway	6"

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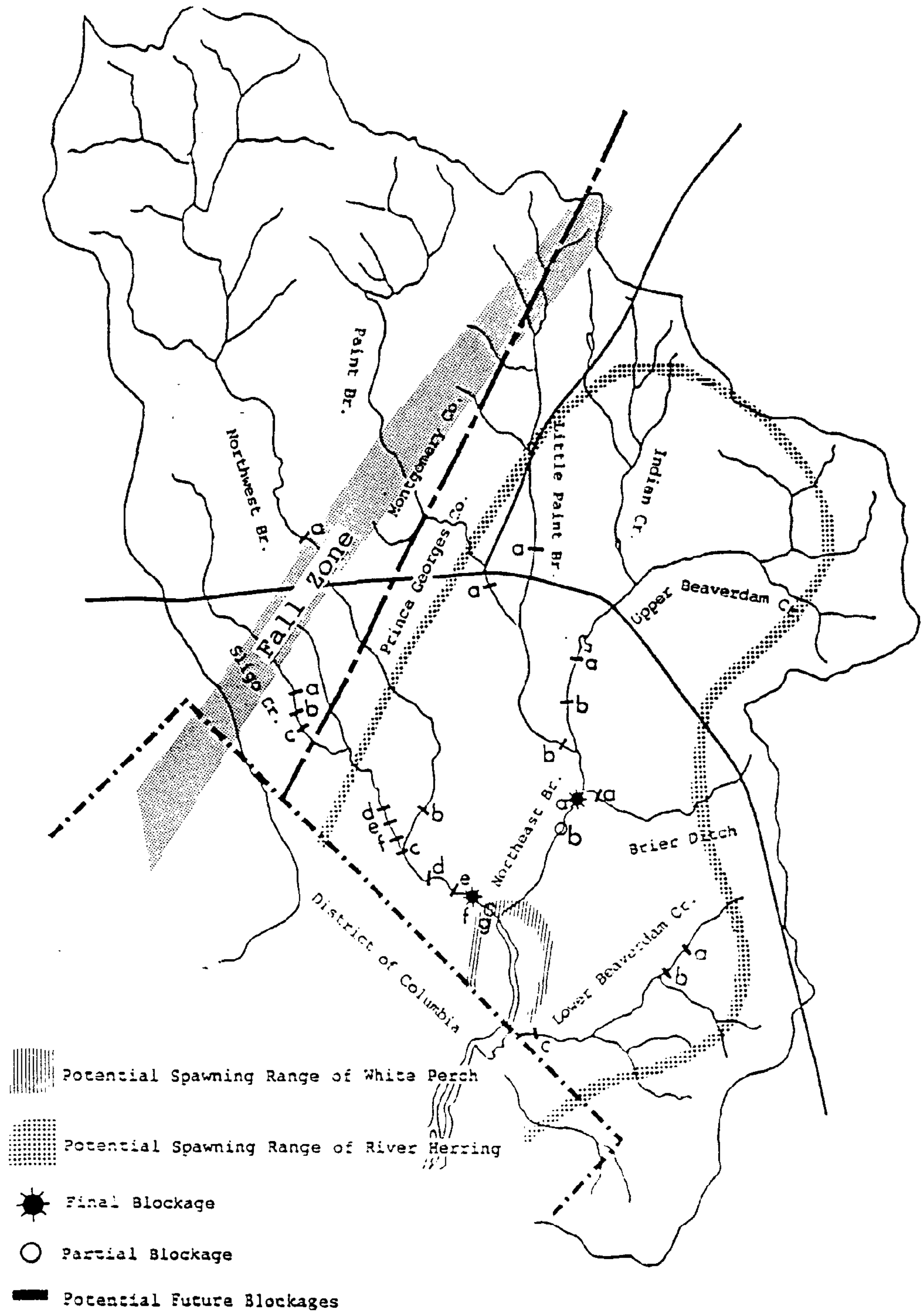

Figure 11. Map of blockages to migratory fishes in the Anacostia River Basin with potential spawning ranges (source: ICPRB, 1989). See Table for description of blockages.

V. FISH DISTRIBUTION PATTERNS

The present distribution of fishes in the Anacostia can be partially explained by available information on fish habitat requirements and environmental conditions in the basin. The two environmental variables that would appear most limiting to Trout population are water temperature and volume flows. As discussed previously, maximum temperatures in the lower portion of the basin are unfavorable for trout, but water temperature alone does not distinguish Paint Branch from the other upper tributaries in which reproducing Trout populations do not occur. Rainbow Trout are stocked in the upper Northwest Branch, which supports a put-and-take fishery but not Trout reproduction. Based on available water temperature data, Upper Beaverdam and Indian Creeks could also potentially support a put-and-take Trout fishery.

Volume flows and variability in discharge rates measured at the two USGS gage sites in the lower basin would also be unfavorable for Trout, as well as for other fish. Although data are lacking, there are likely to be lower rates and variability in discharge in the upper tributaries, as mentioned previously for Paint Branch, which would make these areas more favorable habitat for Trout and other fish.

In the absence of more detailed habitat information, we can only speculate on the causes for the limitation of Brown Trout to Paint Branch. High degrees of sedimentation may prevent spawning in some tributaries, particularly Little Paint Branch and Indian Creek which receive a great deal of sediment from surface mines.

Although the water quality at monitoring stations on Paint Branch is not substantially different from other tributaries in the upper Anacostia River Basin, it should again be noted that these areas are relatively poor Trout habitat (CH_2M Hill, 1980; Galli, 1983). The most detailed habitat analysis of the highest quality Trout habitat on Paint Branch was conducted by CH_2M Hill (1980). They utilized a model developed by Binns and Eiserman (1979) which predicts Trout standing crop based on semiquantitative measurements of water quality, flow patterns, and habitat structure. Although the utility of this model has been questioned (Bowlby and Roff, 1986), it would be useful to gather such habitat and flow data in other portions of the Anacostia River basin that would potentially support trout populations.

Bowlby and Roff (1986) found a negative relationship between microbial biomass and trout biomass in Ontario streams. The violations of Maryland fecal coliform standards in much of the Anacostia River Basin are indicators of high microbial biomass, as well as generally poor water quality. Coliform levels are relatively low at monitoring stations on Paint Branch, as noted previously, and are likely to be even lower in the spring-fed headwaters. Bowlby and Roff (1986), in fact, hypothesize that low microbial biomass is a surrogate measure of localized groundwater discharge, which, in turn has beneficial effects on microhabitat for Trout eggs and larvae. Groundwater discharge maintains cool temperatures and stable minimum flowrates and may have other beneficial effects on Trout populations. Thus, a stronger influence from groundwater discharge in upper Pain Branch than in the other tributaries probably is a major factor in its suitability as Trout habitat.

Finally, the present distribution of Trout in the Anacostia River Basin could reflect the historical stocking record. Brown Trout have been stocked only in Paint Branch. It is probable that high water temperatures and poor water quality in Lower Paint Branch and Little Paint Branch have prevented dispersal of Brown Trout to other tributaries, such as the Northwest Branch or Upper Beaverdam Creek.

In the lower Anacostia River Basin, the most depauperate fish faunas were found in Lower Beaverdam Creek and Sligo Creek. Of the targeted species, only Bluegill were found in Lower Beaverdam Creek. Lower Beaverdam Creek is one of the more heavily developed portions of the river basin, with a considerable amount of industrial and commercial activity in close proximity to the creek (COG, 1986). Coliform levels are relatively high in most of Lower Beaverdam Creek (Figure 7), indicating generally poor water quality. Water temperatures in Lower Beaverdam are also among the highest in the Anacostia basin, although the maximum measured temperatures should be tolerable to warmwater fishes. Habitat for fish is also likely to be poor on Lower Beaverdam Creek, due to the presence of a large amount of trash and debris that has been dumped in the creek. On November 12-13, 1988 there was a major joint effort of the Maryland National Guard, Maryland's Departments of Natural Resources and Environment, Prince George's County Department of Environmental Resources, Interstate Commission on the Potomac River Basin and Washington Suburban Sanitary Commission to remove some of the large and heavy debris, including rusted automobiles, dry rotted tires, and gasoline tanks. It is hoped that these cleanup efforts will contribute to improvements in water and habitat quality in Lower Beaverdam Creek.

The paucity of fish in Sligo Creek is not readily explained by available information on water and habitat quality. Coliform levels are relatively low for much of the length of Sligo Creek (Figure 7), and water temperatures are favorable for warmwater fishes (Figures 5 and 6). One possible explanation for the poor fish populations in Sligo Creek is toxic substances. Sligo Creek is one of the most heavily urbanized areas in the Anacostia River basin, and the Sligo Creek Parkway runs adjacent to the creek for much of its length. As discussed previously, there is substantial information on toxic substances only for two stations on Paint Branch, both of which show alarmingly high concentrations of trace metals. It would be desirable to gather further information on toxic substances in Sligo Creek and other areas in the basin.

An alternative explanation for the depauperate fish fauna in Sligo Creek is that the areas has not recovered from recent disturbances. Periodic flooding has been cited as one of the major problems in Sligo Creek (COG, 1986). Unusually high stormwater discharges may wash fish populations downstream, and stream blockages may prevent subsequent upstream migration. Figure 11 shows there are a number of obstructions to fish movement in Lower Sligo Creek. If this is the problem, introductions of warmwater fish to Sligo Creek could temporarily restore desirable fish populations, but a permanent solution would require removal of blockages to fish movement.

VI. MODELING REVIEW

Camp, Dresser and McKee (1986) evaluated 20 instream flow methods that focused on aquatic life protection requirements. The study concluded that the Tennant Method was the best minimum instream flow estimation for state wide application. A major factor in this decision was the popularity of the method and its ease of use (the Tennant Method was applied to the Anacostia Basin in the present study). The second recommendation was the U.S. Fish and Wildlife Services Instream Flow Incremental Method. This method was recommended for studies where more detailed information than a broad state-wide index is required on the aquatic life of a river reach. Therefore this method was researched and will be summarized next in regards to its structure and possible application to the Anacostia River basin.

VI.1. INSTREAM FLOW INCREMENTAL METHOD

The incremental method allows for evaluation of the factors affecting different life stages of a species. The method integrates both micro and macro habitat concepts. Fish and macroinvertebrates respond to the microhabitat conditions that are associated with the macrohabitat. Macrohabitat is dependent on the geology, elevation, slope, and water supply. Microhabitat includes channel geometry, substrate and cover. Microhabitat measurements are typically made in locations that reflect changes in macrohabitat. The decision variable generated in IFIM is total habitat area for fish or food organism. Habitat in IFIM includes physical channel characteristics, streamflow, and water quality. IFIM helps to evaluate the habitat suitablility of a stream by a step by step methodology and can be used to assess the effects of future land use changes on the habitat suitablility. The result is a quantification of the amount of potential habitat available for each life history state of a species as a function of streamflow. Modeling of water quality parameters and hydraulic processes can be done by simplified methods as suggested in Camp, Dresser and McKee (1986) or by more sophisticated engineering/scientific models such as the U.S. Army Corps of Engineers HEC series or the EPA's Hydrologic Simulation Program Fortran (HSPF). This will be discussed in later sections.

Figure 12 is a block diagram for the overview of the analytical sequence performed in an IFIM application. The shaded areas show where individual water quality, hydraulic and/or hydrologic models may be necessary.

Periodicity tables must be created for each targeted species so that necessary microhabitat conditions in the stream are evaluated at the time they are needed. An example of a periodicity table that was constructed for smallmouth bass is shown in Figure 13. IFIM was originally developed for western streams, however the fishery habitat requirements created as part of the present report could be used as the basis for these periodicity tables in the Anacostia.

A computer program that is an integral part of the IFIM is the Physical Habitat Simulation System (PHABSIM). Processed field data are entered into the PHABSIM program and it generates data that describe the reach as a series of small cells (Figure 14). Velocity, depth, substrate and cover are assumed homogeneous within each cell. Various computer models for simulating changes in water quality, temperature, flow and channel morphology can be linked with PHABSIM (this is discussed in more detail in following sections). A Suitablility Index (SI) for velocity, depth, substrate and cover in each cell is determined by the use of SI curves for each life stage (Figure 15). A user selected aggregation technique is used to estimate the composite suitablity for that combination of variables (FWS, 1982).

A Weighted Usable Area (WUA) is then derived for each cell for each life stage and flow. Simulations can be produced for selected unmeasured flows for existing and proposed activites and their effect on the distribution of microhabitat variables. When WUA values are plotted for each flow, a flow/microhabitat function is produced for each reach (see Figure 16). Water quality simulations can be integrated into this process for the same specified flows. Total habitat is a complete expression of the functional relationship between WUA, water quality, and streamflow. This is expressed as the product of the WUA times the length of stream with suitable water quality for a specified flow for each life stage of the targeted species. This provides the linkage with water quality assessments

Camp, Dresser and McKee (1986) provide a checklist of activities to accomplish for an application of IFIM. The types of data required for this type of study can be extracted from this list (Figure 17). Data needs for the water quality/hydrology models will be discussed later. The Oak Ridge National Laboratory (Loar and Sale, 1981) compared several types of instream flow assessment techniques and lists data requirements of each method. That study also cites IFIM as the most comprehensive of all the instream flow methodologies for fish resources and more detailed data requirements can be found in that report.

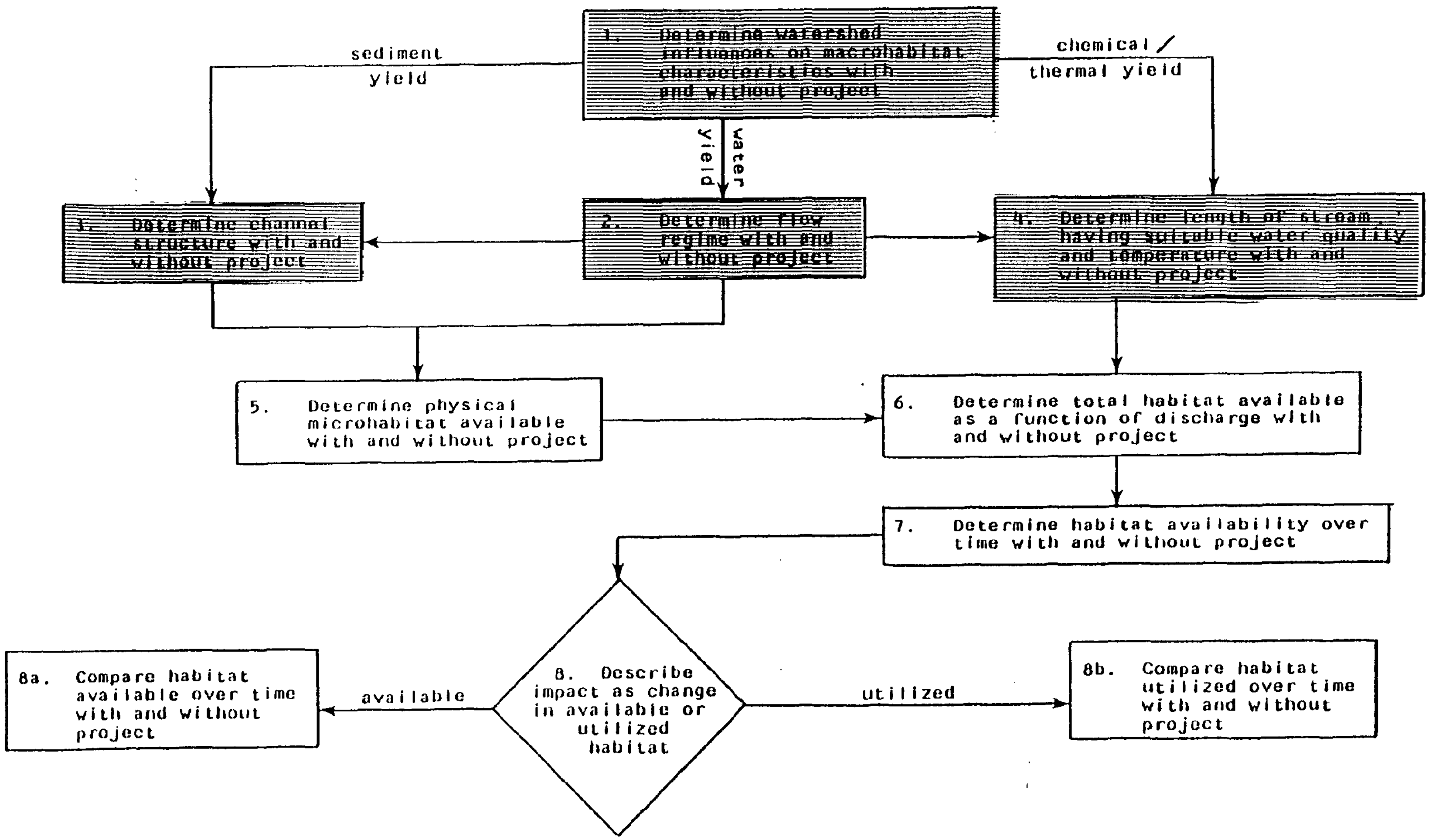

Figure 12. Overview of the analytical sequence performed in an application of the IFIM (source: Bovee, 1982).

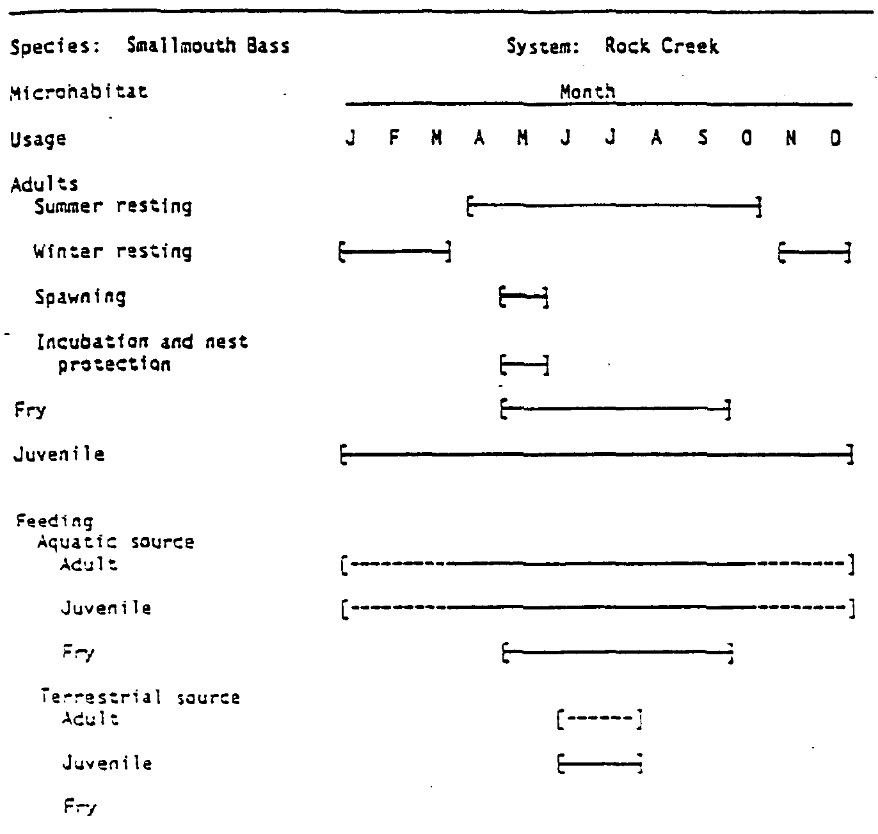

Figure 13. Example of a periodicity table for Smallmouth Bass (source: Bovee, 1982).

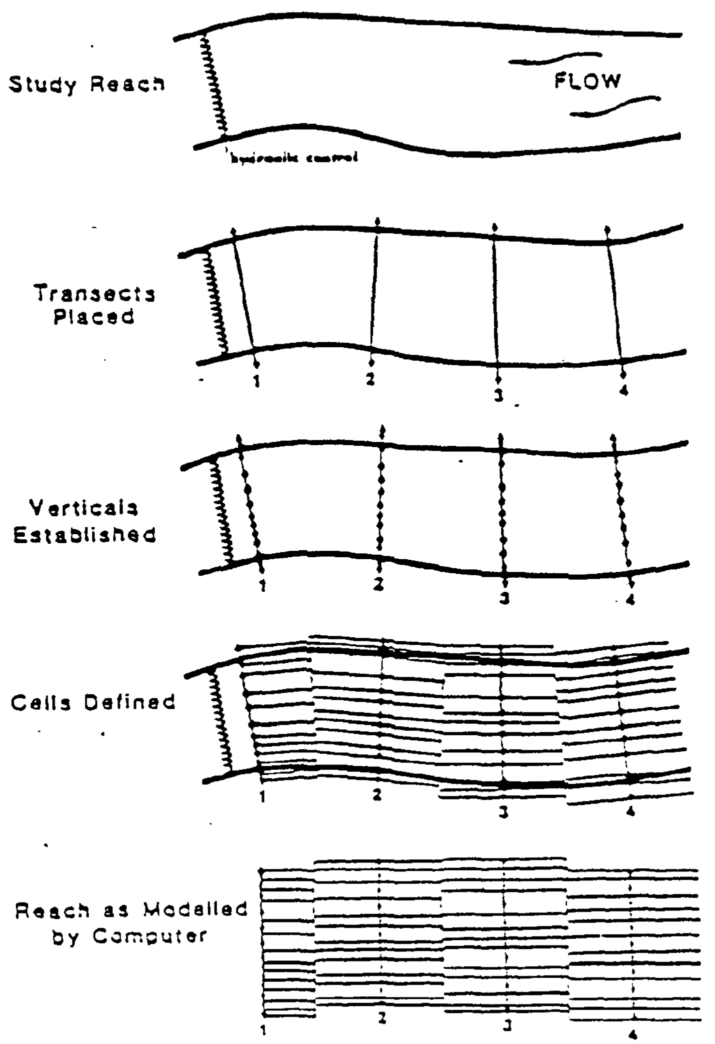

Figure 14. Subdivision of a study reach for IFIM hydraulic modeling (source: Bain et al., 1982).

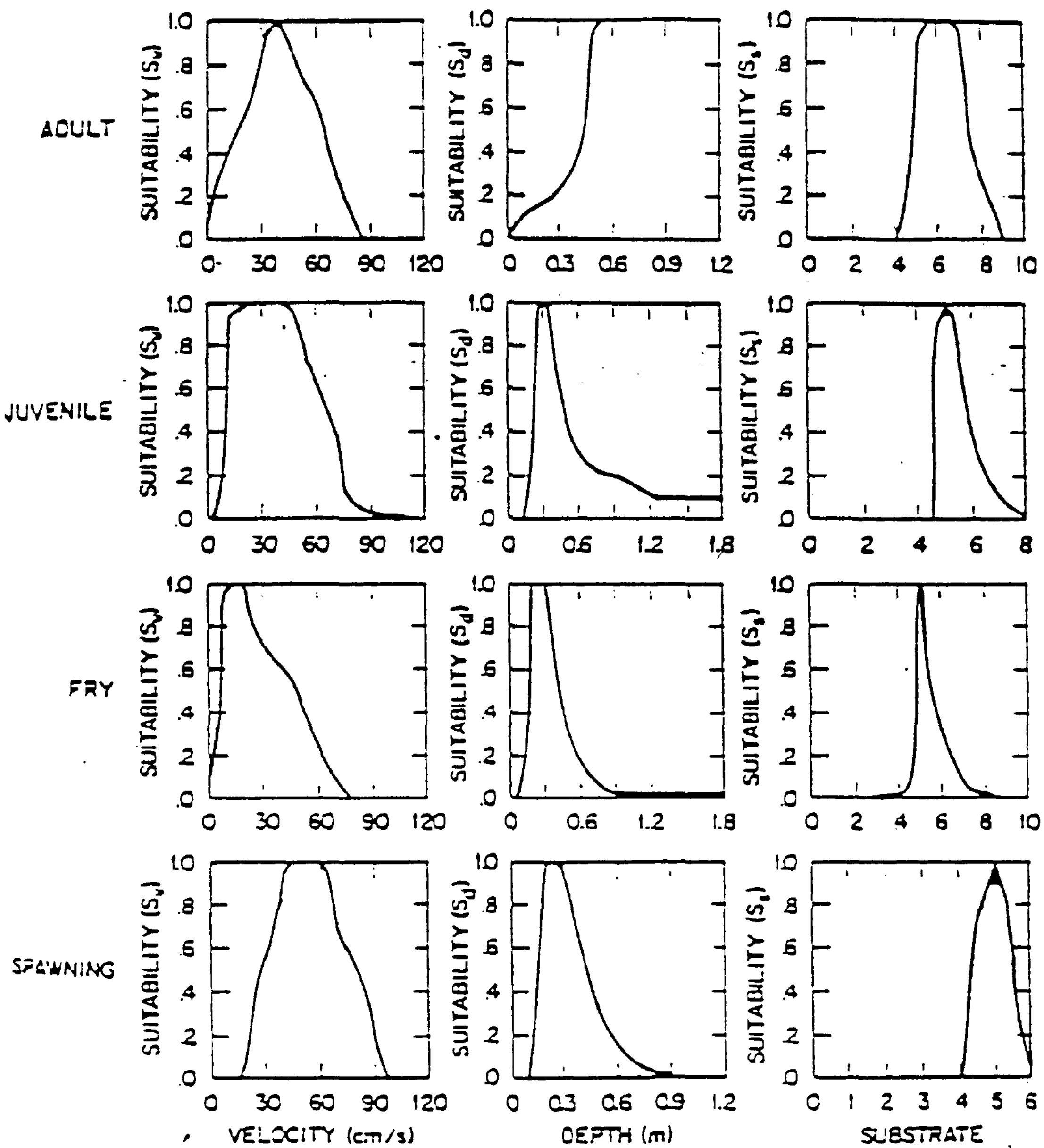

Figure 15. Habitat suitability functions for Rainbow Trout (source: Bovee, 1982).

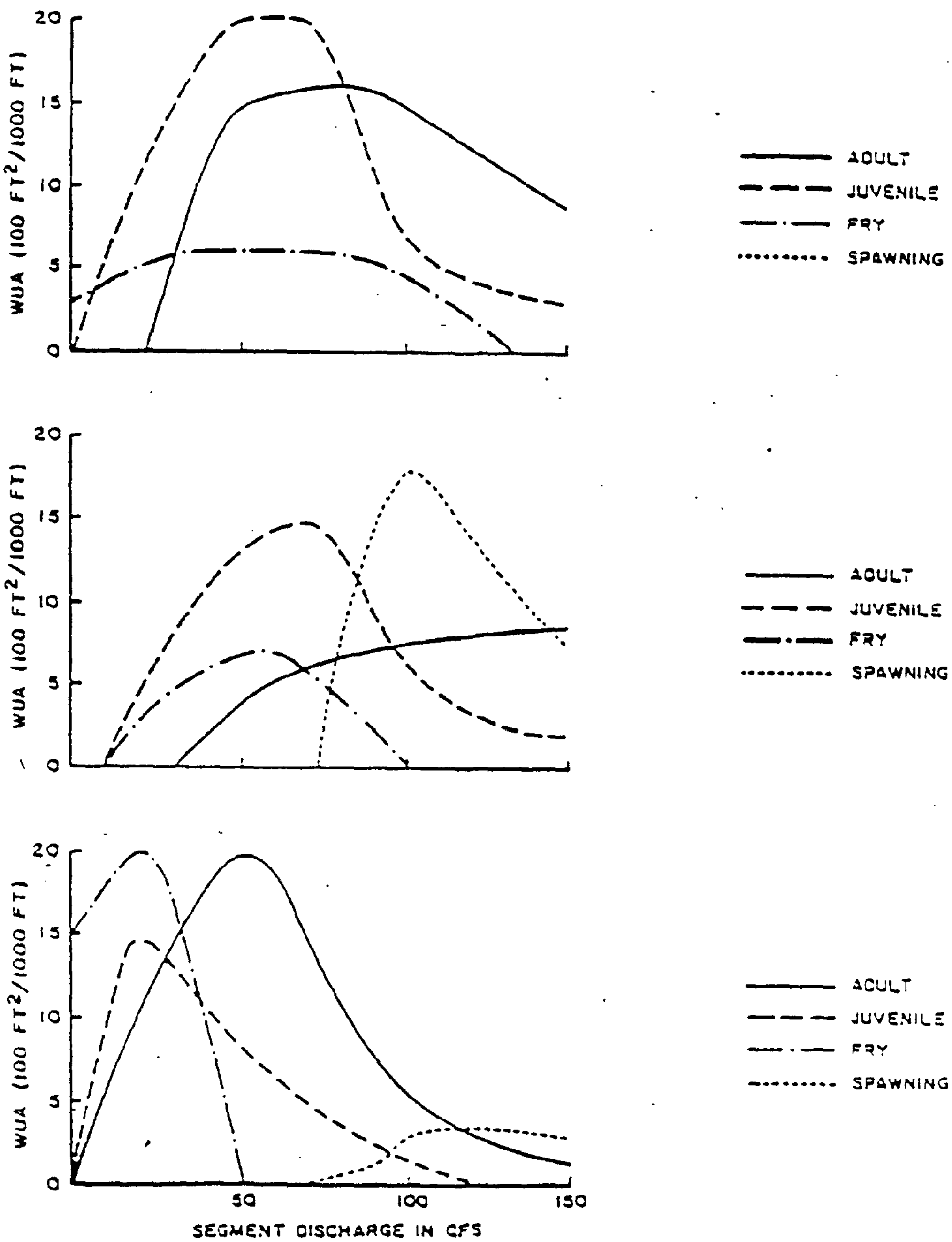

Figure 16. Example weighted usable area versus discharge curves for three study reaches (source: Bovee, 1982).

- ____ Study objectives have been identified and stated.
- ____ Project area has been reconnoitered.
- ____ Length of mainstem to be included in study has been determined.
- ____ Environmental conditions affected by proposed action have been identified (check those which apply):
  - ____ Watershed
  - ____ Channel structure
  - ____ Water quality
  - ____ Temperature
  - ____ Flow regime
- ____ Initial contacts with professional personnel have been made.
- ____ Tributaries to be included in study have been identified, if applicable.
- ____ Topographic maps of area have been obtained.
- ____ Geologic maps of area have been obtained, if available.
- ____ Streamflow records for area have been obtained.
- ____ Arrangements have been made to develop synthetic hydrographs for ungaged streams.
- ____ Equilibrium conditions of watershed and channel have been evaluated.
- ____ Arrangements have been made to model future channel structure, if necessary.
- ____ Existing water quality characteristics have been evaluated and screening equations applied to determine future water quality status.
- ____ Arrangements have been made to model future water quality, if necessary.
- ____ Longitudinal distribution of species has been determined.
- ____ Evaluation species have been selected.
- ____ Pertinent details of target species have been compiled (life history, food habits, water quality tolerances, and micro-habitat usage).
- ____ Periodicity charts for target species have been prepared and referenced to stream segments (see Chapter 3).
- ____ Display and interpretation requirements have been determined and acquisition of biological data, if required, has been included in study design (see Chapter 5).

Figure 17. Checklist for a typical application of IFIM (source: Camp Dresser & McKee, 1986).

IV.2. RELATED STUDIES

The Potomac River flow-by study by the Maryland DNR (MD DNR, 1981) applied IFIM in a section of the Potomac River. That study reports that the methodology proved to be a useful tool for analyzing relative changes in habitat availablity at various flows. However the study listed several limitations encountered with the model such as hampered data collection due to the complexity of the size of the stretch of the Potomac River analyzed, and the model does not establish a <u>direct</u> relationship of habitat availability to changes in water quality.
As previously mentioned, water quality concerns are addressed in the IFIM, however the simulation of water quality changes due to land use must be done with external models.

The University of North Carolina (Medina, 1982), developed a comprehensive approach to integrate the impact of water quality for instream flow strategies. Through a network of sub-models, this approach allows the user to interpret results in terms of the frequency of occurence of water quality violations in a stream reach as well as the duration of the violations. The models used in this method are the storage/treatment and receiving water quality frequency and duration model (STO/TRT RECEIVING), RFREQ for rainfall frequency analysis, RATING which converts streamflow stage data to discharge, the Synoptic Rainfall Data Analysis Program (SYNOP), the Distributed Routing Rainfall-Runoff Model Version II (DR3M) and the U.S. Army Corps of Engineers Storage, Treatment, Overflow, Runoff Model (STORM). The rainfall models of the UNC methodology are used to select rainfall time series that are of statistical importance to the particular drainage basin. These time series are then used with DR3M which utilizes a network of discrete overland flow and streamflow segments to produce runoff time series. STORM is used to generate the pollutant loadings in the drainage basin. STO/TRT RECEIVING combines the point and non-point loads and simulates mixing with receiving stream upstream loads to obtain water quality concentrations in time and space, cumulative water quality frequency curves and frequency distributions.

The Anacostia River Water Quality Facility Plan was completed by Saitherwaite and Associates (1988) for the Washington Suburban Sanitary Commission. That report utilized information from a project being done by another contractor (for Maryland Water Resource Authority) that included modeling efforts for the assessment of future land use condition flood plains and mitigation strategies. The Soil Conservation Service model TR20 (U.S. Soil Conservation Service, 1987) and the U.S. Army Corps of Engineers HEC2 (Hydrologic Engineering Center, 1979) were utilized in the latter study and thus a large amount of data on existing and proposed land use, soils and channel cross sections were aquired and digitized. The WSSC study assessed the future land use of the basin (for Prince George County) as it might effect water quality. The Washington Council of Governments 'Simple Method' (Schueler, 1987) was used to estimate stormwater pollutant export potential under existing and future land use conditions (parameters analyzed were: Phosphorus, Nitrogen, COD, BOD, Zinc, Lead, and Copper), and HEC2 runs were made to locate areas with potential 'erosive' velocities.

The Montgomery County portion of the Anacostia basin was also studied and modeled. CH2M Hill etc. (1982) applied the Hydrocomp Simulation Program on this portion of the basin to simulate existing and future water quality conditions due to planned future land use changes. Several water surface profiles were also created with HEC-2.

SUMMARY

This study assessed water quality in the Anacostia River basin by analyzing data from water quality monitoring stations from different jurisdictions in the basin. The data were recorded as part of the corresponding jurisdictions periodic water quality monitoring program. The present and potential distributions of selected cool-water, warm-water and migratory fishes were also determined and relationships with water quality and instream blockages were assessed.

Analyses showed that most of the commonly recorded water quality parameters (e.g. dissolved oxygen, temperature) are not an obvious problem in the basin. However it is important to note that the data used to make these analyses were recorded at different intervals of time and data sets may or may not be consistent between jurisdictions. In addition, there was relatively little information available on toxic substances. Therefore it would be premature to conclude that water quality is not a factor in fish distributions. There are documented cases of sedimentation problems in the basin and, coliform levels are quite high in many of the streams. Also, it is quite possible that water quality problems in the basin are crucially linked to specific episodic pollution events. These types of occurences could easily be missed in a regular water quality monitoring schedule.

Tangible results of fishery habitat enhancement could be realized through several management actions. This report stressed three general practices that may prove the most beneficial. It was shown that relatively small parcels of land have been implicated as the source of a large percentage of the sediment problem in the basin. The persistent sedimentation and related habitat degredation problems in the basin could be lessened by reclamation of surface mines. Secondly, extensive flood and erosion control practices have left large areas of riparian habitat severely degraded. This study points out that introduction of fringe marshes in selected areas, particularily where streambank rip-rap has been applied, could enhance habitat quality in several ways. Finally, removal and or modification of instream blockages to migratory fish could open upstream waters in several locations within the basin.

Several instream flow methodologies were scrutinized for their potential application to the Anacostia basin and its unique living resource problems. It seems that the IFIM would be the best currently available tool to assess the instream flow needs of the living resources in the basin. The IFIM has been shown to be the most comprehensive methodology in regards to the factors affecting instream flow

needs of living resources. The method has the added benefit of allowing the user to incorporate the most appropriate water quality and hydraulic models into the methodology. It is concluded that the IFIM has the most potential, of those models assessed, to explain the current distribution of fish species in terms of instream flow requirements, and also to serve as a tool for future planning decisions.

The IFIM does have some drawbacks such as the large amount of field work and data required. Additional information required for the IFIM includes additional species specific habitat data, (beyond that available for this report), stream profiles and cross sections, synthetic hydrographs, and storm water quality sampling.

The data needs and modeling capabilities for IFIM will vary depending on the size of the watershed to be studied.
A pilot project to implement the IFIM on a single tributary within the Anacostia basin is recommended before proceeding to implement IFIM on the entire Anacostia. Experience gained from this pilot project would help provide insight into the IFIM methodology, and facilitate future applications of the method to other parts of the Anacostia basin. This would eventually lead to the most efficient and practical application of the methodology to the entire drainage basin.

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APPENDIX I
Summaries Of Water Quality Data For Selected Parameters.

In left column are station ID codes, collecting agency code, and period of record. Each station has two ID codes: the code in parentheses is used in Figures 5-7, and the second code is the one used by the collecting agency. Agencies are Prince Georges County Health Department (PGHD), Montgomery County (MONT), and Maryland Office of Environmental Programs. The right column shows median, maximum, minimum, and number of observations for total coliforms (T.COL.), dissolved oxygen (DO), pH (pH), temperature (TEMP.), total suspended solids (TSS), and turbidity (TURB.).

			T.COL. mpn/100ml	DO mg/l	pH SU	TEMP. C	TSS mg/l	TURB. JTU
Station	(A) 50090	Med.	2,250	10.25	7.1	12.	NA	4.8
Agency	MONT	Max.	110,000	15.4	8.7	23.	NA	270.
Record	710125 - 801204	Min.	230	5.8	3.5	0.	NA	2.0
		Nbr.	14	142	131	136	NA	39
Station	(B) 50100	Med.	2,400	10.2	7.2	11.	NA	4.3
Agency	MONT	Max.	110,000	15.0	8.6	22.	NA	900.
Record	710125 - 801204	Min.	230	6.8	3.8	0.	NA	1.4
		Nbr.	13	140	129	137	NA	38
Station	(C) 50080	Med.	2,400	10.2	7.3	13.	NA	5.2
Agency	MONT	Max.	110,000	15.2	8.7	23.	NA	220.
Record	710125 - 880428	Min.	230	6.1	3.5	0.	NA	1.3
		Nbr.	16	156	147	151	NA	40
Station	(D) 50120	Med.	930	10.2	7.1	12.	2.25	4.
Agency	MONT	Max.	240,000	14.4	9.2	22.	4.0	110.
Record	710114 - 880907	Min.	93	7.1	6.0	0.	0.5	1.
		Nbr.	20	149	142	150	2	43
Station	(E) 50070	Med.	7,800	10.1	7.1	12.	NA	7.7
Agency	MONT	Max.	240,000	15.3	8.9	23.	NA	200.
Record	710125 - 801204	Min.	2,400	6.3	3.1	0.	NA	2.2
		Nbr.	14	143	131	137	NA	39
Station	(F) 50060	Med.	2,400	10.0	7.2	13.	0.75	6.5
Agency	MONT	Max.	110,000	15.2	8.8	23.	1.0	260.
Record	710125 - 880907	Min.	240	6.2	2.9	0.	0.5	2.8
		Nbr.	16	159	151	156	2	39
Station	(G1) 59010	Med.	4,765	11.2	7.0	8.5	10.0	3.1
Agency	MONT	Max.	11,000	14.8	9.4	33.0	10.0	12.
Record	731116 - 801201	Min.	150	6.6	5.9	0.0	10.0	1.
		Nbr.	4	47	47	43	1	13
Station	(G2) 59020	Med.	4,865	10.7	6.9	8.	14.0	2.2
Agency	MONT	Max.	11,000	14.8	8.4	30.	14.0	12.0
Record	731116 - 840802	Min.	150	6.0	5.7	0.	14.0	0.6
		Nbr.	4	45	46	42	1	13
Station	(G3) 59030	Med.	2,765	11.0	7.0	8.	5.0	2.6
Agency	MONT	Max.	24,000	13.8	8.2	28.	5.0	8.2
Record	731116 - 840802	Min.	73	6.0	6.2	0.	5.0	1.4
		Nbr.	4	47	48	44	1	13
Station	(G4) 59040	Med.	1,365	8.25	6.55	5.	NA	16.0
Agency	MONT	Max.	11,000	12.5	7.2	23.	NA	125.0
Record	731116 - 801201	Min.	230	0.4	5.6	0.	NA	1.5
		Nbr.	4	30	30	30	NA	9

APPENDIX 1 (Continued)

			T.COL. mpn/100ml	DO mg/l	pH SU	TEMP. C	TSS mg/l	TURB. JTU
Station	(H) A-20	Med.	15,000	10.22	6.86	9.75	NA	NA
Agency	PGHD	Max.	43,000	15.0	8.08	23.	NA	NA
Record	731218 - 801202	Min.	930	4.9	5.4	0.	NA	NA
		Nbr.	16	59	59	60	NA	NA
Station	(I) A-11	Med.	4,300	11.03	6.9	12.	NA	NA
Agency	PGHD	Max.	75,000	15.0	10.36	28.	NA	NA
Record	731218 - 810106	Min.	750	7.6	6.	0.	NA	NA
		Nbr.	16	58	59	59	NA	NA
Station	(J) 50113	Med.	1,675	NA	NA	NA	NA	NA
Agency	MONT	Max.	110,000	NA	NA	NA	NA	NA
Record	800709 - 870302	Min.	4	NA	NA	NA	NA	NA
		Nbr.	76	NA	NA	NA	NA	NA
Station	(K) A-14	Med.	4,300	10.	6.59	10.	NA	NA
Agency	PGHD	Max.	240,000	15.0	8.1	22.	NA	NA
Record	731218 - 810106	Min.	150	4.8	5.15	0.	NA	NA
		Nbr.	16	60	59	61	NA	NA
Station	(L) A-15	Med.	12,150	9.4	6.5	10.	NA	NA
Agency	PGHD	Max.	1,100,000	15.0	8.55	24.	NA	NA
Record	731218 - 801202	Min.	93	3.	5.49	0.	NA	NA
		Nbr.	16	55	56	58	NA	NA
Station	(M) A-17	Med.	19,500	10.03	6.8	10.	NA	NA
Agency	PGHD	Max.	240,000	15.0	7.7	23.	NA	NA
Record	731218 - 801202	Min.	430	4.86	5.6	0.	NA	NA
		Nbr.	16	58	58	59	NA	NA
Station	(N) A-10	Med.	5,900	11.73	7.2	10.	NA	NA
Agency	PGHD	Max.	15,000	15.4	10.62	26.	NA	NA
Record	731218 - 801202	Min.	93	7.2	6.2	0.	NA	NA
		Nbr.	16	56	58	59	NA	NA
Station	(O) 58030	Med.	2,400	10.35	7.0	13.	0.1	4.75
Agency	MONT	Max.	240,000	14.7	8.2	23.	0.11	370.0
Record	700128 - 820125	Min.	430	7.4	6.4	0.	0.11	1.1
		Nbr.	21	142	112	119	1	46
Station	(P) 50050	Med.	4,600	10.0	7.3	13.	NA	7.05
Agency	MONT	Max.	240,000	15.3	8.6	24.	NA	200.
Record	710125 - 801204	Min.	430	6.8	2.7	0.	NA	2.1
		Nbr.	13	140	131	136	NA	38
Station	(Q) 50030	Med.	2,400	10.0	7.2	12.	17.	2.45
Agency	MONT	Max.	24,000	15.4	10.1	24.	26.	130.0
Record	710114 - 871215	Min.	91	5.8	1.5	0.	8.	0.5
		Nbr.	15	148	146	149	2	36
Station	(R) 50037	Med.	4,600	10.0	7.2	14.0	4.0	4.8
Agency	MONT	Max.	240,000	15.6	8.7	27.2	96.0	200.
Record	710618 - 880907	Min.	240	7.0	2.6	0.0	0.5	1.2
		Nbr.	51	140	179	184	39	38
Station	(S) A-12	Med.	23,000	10.3	7.	13.	NA	NA
Agency	PGHD	Max.	1,100,000	15.0	9.61	28.	NA	NA
Record	731218 - 801008	Min.	290	6.	4.8	0.	NA	NA
		Nbr.	16	55	54	57	NA	NA

APPENDIX 1 (Continued)

Station / Agency / Record		Stat.	T.COL. mpn/100ml	DO mg/l	pH SU	TEMP. C	TSS mg/l	TURB. JTU
Station	(T) 50020	Med.	4,600	10.3	7.4	12.	NA	2.95
Agency	MONT	Max.	24,000	16.1	9.7	25.	NA	150.
Record	710114 - 840621	Min.	150	6.8	2.1	0.	NA	1.2
		Nbr.	13	133	127	131	NA	36
Station	(U) A-16	Med.	43,000	11.8	7.1	10.5	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	8.5	26.	NA	NA
Record	731218 - 801202	Min.	43	6.	4.7	0.	NA	NA
		Nbr.	16	57	57	58	NA	NA
Station	(U) 50040	Med.	NA	11.35	7.55	7.5	NA	NA
Agency	MONT	Max.	NA	12.4	9.0	21.0	NA	NA
Record	710125 - 710609	Min.	NA	9.0	6.9	0.0	NA	NA
		Nbr.	NA	18	16	18	NA	NA
Station	(V) A-9	Med.	9,300	11.16	7.2	10.	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.3	30.	NA	NA
Record	731218 - 800806	Min.	390	6.4	5	0.	NA	NA
		Nbr.	16	55	54	57	NA	NA
Station	(W) A-5	Med.	43,000	10.99	7.3	13.0	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	8.86	28.0	NA	NA
Record	731218 - 801006	Min.	1,200	5.9	5.2	0.0	NA	NA
		Nbr.	15	58	58	59	NA	NA
Station	(X) 50010	Med.	2,400	10.0	7.4	13.0	4.0	2.75
Agency	MONT	Max.	46,000	15.2	11.7	27.2	40.0	160.
Record	710114 - 880907	Min.	230	6.9	0.5	0.0	0.5	1.2
		Nbr.	49	151	190	194	38	36
Station	(Y) A-18	Med.	26,000	11.0	7.435	11.5	NA	NA
Agency	PGHD	Max.	1,100,000	15.0	8.82	27.	NA	NA
Record	731218 - 810106	Min.	750	5.8	5.4	0.	NA	NA
		Nbr.	16	61	60	62	NA	NA
Station	(Z) A-6	Med.	23,000	10.8	7.445	12.0	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.17	29.0	NA	NA
Record	731218 - 801202	Min.	750	1.52	5.4	0.0	NA	NA
		Nbr.	16	60	60	61	NA	NA
Station	(AA) A-13	Med.	12,000	11.6	7.25	11.	NA	NA
Agency	PGHD	Max.	240,000	15.0	9.7	32.	NA	NA
Record	731218 - 801203	Min.	640	4.9	5.1	0.	NA	NA
		Nbr.	15	57	55	59	NA	NA
Station	(AB) A-8	Med.	23,000	9.75	7.1	11.	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.05	29.	NA	NA
Record	731218 - 801203	Min.	1,200	6.4	4.8	0.	NA	NA
		Nbr.	16	58	56	59	NA	NA
Station	(AC) A-7	Med.	16,150	11.18	7.3	12.	NA	NA
Agency	PGHD	Max.	1,100,000	15.0	9.8	31.	NA	NA
Record	731218 - 801203	Min.	1,500	4.2	5.1	0.	NA	NA
		Nbr.	16	57	54	58	NA	NA
Station	(AD) A-4	Med.	43,000	11.45	7.5	13.5	NA	NA
Agency	PGHD	Max.	460,000	15.0	8.85	32.0	NA	NA
Record	731218 - 801203	Min.	2,300	6.52	4.9	0.0	NA	NA
		Nbr.	16	60	59	62	NA	NA

APPENDIX 1 (Continued)

Station / Agency / Record		Stat.	T.COL. mpn/100ml	DO mg/l	pH SU	TEMP. C	TSS mg/l	TURB. JTU
Station	(AF) B-10	Med.	1,900	9.5	7.2	13.75	NA	NA
Agency	PGHD	Max.	93,000	15.0	9.09	28.	NA	NA
Record	730228 - 810120	Min.	0	5.6	3.46	0.	NA	NA
		Nbr.	34	67	66	64	NA	NA
Station	(AG) B-3	Med.	13,500	9.72	7.4	15.	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.2	28.	NA	NA
Record	730123 - 810120	Min.	210	3.9	5.9	0.	NA	NA
		Nbr.	28	60	59	62	NA	NA
Station	(AH) B-8	Med.	39,000	10.06	7.35	15.	NA	NA
Agency	PGHD	Max.	11,000,000	15.0	9.21	27.5	NA	NA
Record	730123 - 801217	Min.	930	3.9	6.2	0.	NA	NA
		Nbr.	27	59	58	61	NA	NA
Station	(AI) B-9	Med.	19,000	9.2	7.3	14.	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.5	32.	NA	NA
Record	730123 - 801217	Min.	750	5.6	6.0	0.	NA	NA
		Nbr.	28	59	58	61	NA	NA
Station	(AJ) B-2	Med.	18,000	10.2	7.6	15.5	NA	NA
Agency	PGHD	Max.	1,100,000	15.0	10.97	30.	NA	NA
Record	730123 - 801217	Min.	930	3.4	6.0	0.	NA	NA
		Nbr.	28	59	59	60	NA	NA
Station	(AK) ANA0082	Med.	9,300	10.5	7.1	12.0	8.	15.0
Agency	OEP	Max.	2,400,000	15.2	8.7	31.0	42.	127.
Record	800408 - 870602	Min.	0	4.99	6.0	0.6	1.	7.2
		Nbr.	63	80	76	81	17	17
Station	(AL) B-1	Med.	9,300	9.45	7.3	14.	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.35	28.	NA	NA
Record	730123 - 801217	Min.	0	5.0	3.46	0.	NA	NA
		Nbr.	62	126	125	125	NA	NA
Station	(AM) B-4	Med.	23,000	9.5	7.485	13.5	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.71	28.	NA	NA
Record	730123 - 810120	Min.	930	5.3	6.0	0.	NA	NA
		Nbr.	28	60	60	62	NA	NA
Station	(AN) B-5	Med.	9,300	11.8	7.7	14.5	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.7	28.	NA	NA
Record	730123 - 801217	Min.	230	4.0	6.0	0.	NA	NA
		Nbr.	28	60	60	62	NA	NA
Station	(AO) B-6	Med.	12,150	10.2	7.4	12.5	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.4	26.	NA	NA
Record	730123 - 801217	Min.	150	5.0	5.9	0.	NA	NA
		Nbr.	28	59	58	61	NA	NA
Station	(AP) B-7	Med.	9,300	10.02	7.3	14.5	NA	NA
Agency	PGHD	Max.	2,400,000	15.0	9.04	27.	NA	NA
Record	730123 - 801217	Min.	75	4.4	6.1	0.	NA	NA
		Nbr.	28	59	58	60	NA	NA